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Utilizing the Next Generation Science Standards as a Framework to Create a Climate Change Curriculum

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UTILIZING THE NEXT GENERATION SCIENCE STANDARDS AS A FRAMEWORK TO CREATE A CLIMATE CHANGE CURRICULUM

by

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CHAPTER ONE

Introduction

My connection to the environment began at an early age with plenty of outdoor play and detailed examples of living environmentally friendly. When I became a teacher I learned that many young people have not had these same experiences and have to be exposed to them at school. These experiences can be shown through experiential education because it creates a meaningful learning experience for students. As a teacher, the state standards dictated what I was allowed to teach. This forced me to be creative when finding content related to environmental studies because there were no environmental state science standards in eighth grade. While planning lessons, I struggled with some of the state standards because the ideas were not woven together. Standards that were in the nature of science and engineering strand (which focus more on scientific practices) were separate from content standards. These standards (ie. argumentation, using maps) were not integrated with the core ideas of Earth Science I was teaching. Because of this frustration, I was drawn to the new Next Generation Science Standards (NGSS). Each standard in the NGSS has a core idea integrated, a scientific practice, and a crosscutting concept making teaching science more accessible. Although I did not use the NGSS while teaching, the science standards that I did use helped me create meaningful science education for my students.

As a science teacher, the Minnesota K-12 Academic Standards in Science were my road map for each school year. The standards told me the stops I needed to take throughout the year, but the length of time at each stop and the route I took with my students was up to me. Even still, the standards were so specific that there was not much choice about what or how to teach the content. An example of this can be seen in the eighth grade astronomy standards. The following benchmark did not allow much room for growth when teaching about the sun: “Recognize that the sun is a medium sized star, one of billions of stars in the Milky Way galaxy, and the closest star to Earth” (Minnesota Department of Education, 2009). Because this benchmark is just meant for recognition of a topic, not an in-depth understanding, the time spent on it was very short. The Minnesota K-12 Academic Standards in Science do not tie together the subject content with scientific and engineering principles, such as asking questions, developing models, or analyzing data. This can leave students confused about how to use their science knowledge in the real world.

For my capstone research project, I created a middle school climate change curriculum that utilizes the NGSS as a framework. The curriculum I created uses the NGSS because they are applicable to the real world. They integrate core science ideas with applications and concepts seen in the science classroom and in real life. Climate change is one of the most important topics for students to understand because the climate is projected to continue to change into the next century and the actions we take now (and students take in their own lifetimes) will determine how severe the impacts are in the future (National Climate Assessment , 2014). Middle school is a great place to dive deep into the science of climate change because students are able to think more abstractly at this age and are old enough to engage in more serious dialogue (Boucher, 2014). This curriculum will be able to help educators and students connect to the environment and learn the science of climate change to make well informed decisions now and in the future, all using the NGSS as a framework.

The NGSS are three-dimensional standards that braid together scientific and engineering practices, crosscutting concepts, and core ideas. They are based on the best and most current research on what constitutes good science education. The three dimensional nature of the standards gives students a body of knowledge to be proficient in and allows them to use that knowledge in the real world and across other science disciplines and subject areas. This three dimensional design of the NGSS is also why educators need instructional support when implementing these standards. Educators need to be aware of all three dimensions when planning lessons and having a good understanding of the NGSS organization is vital.

These standards were new in 2013, therefore there are not a lot of NGSS-supported resources for educators to use with their students. More lessons are slowly becoming available, but it is still not enough. The list is even shorter for NGSS-supported climate change lessons. The curriculum I have written will be used with middle school students that use NGSS as their primary science standards, but could also be used in states that have not adopted the NGSS.

Growing Up: Building a Passion

As I was growing up, my mom taught me how important it was to care for the environment. She taught me a lot about how to live environmentally friendly. I learned what actions people need to take in order to protect our planet. "Never doubt that a small group of thoughtful committed citizens can change the world; indeed, it is the only thing that ever has." This quote from Margaret Mead (30 Inspirational Environmental Quotes, 2001), cultural anthropologist and writer, explains the mentality that my mom instilled in me growing up; everyone can make a difference.

My family did a lot of camping and participated in many outdoor activities when I was young. My sister and I played outside a lot: riding bikes, going to the playground, or gathering the neighbor kids for a game of tag. Watching TV or movies was something we did on rainy days or when it was 20 degrees below zero outside. I loved, and still love being outdoors and understand the importance of protecting and caring for the environment.

This love and care for the environment has played out in many ways. My mom, for example, was an avid recycler when I was young. She made sure I understood the benefits of sorting bottles and cans from the time I was in elementary school. Throughout my life, our recycling bin has always been larger than our garbage bin. It was usually my job to take out the recycling and garbage. It did not take me long to talk my family into recycling every possible item we could. This was only the tip of the iceberg, because I continued to build on these environmental morals throughout school.

During my first year at college, I declared my major as geography. Being outdoors was something I really enjoyed, and I wanted to make maps, or at least use them everyday. I excelled in my science classes and really enjoyed my J-term class: a meteorology internship with a local TV station. Enjoy is actually an understatement, because the class was so great that I changed my major to meteorology. The weather has always fascinated me, so making a career out of a passion just made sense. Unfortunately, the potential hours for a meteorologist was not what I wanted for my career, so I changed my mind again.

My final decision was a secondary education major with an emphasis in Earth and Space Science. The main reason I changed my major to education was the love of sharing knowledge and helping someone learn something new. There were two key moments in college that led me down the education path. The first was my successful involvement with the Big Partner Little Partner program in college. I was paired with a first grade student from a local elementary school and enjoyed hanging out each week. It was meaningful to be able to teach someone and impart knowledge, no matter what it was: doing a cartwheel, working on math facts, or learning the names of the cloud types. The second moment happened during a class at another news station when I was explaining what meteorologists do to a touring school group. In the middle of the explanation, the teacher asked, “Why do they always get it wrong?” It was alarming to me that this science educator did not understand and that she was so blunt about it in front of her class. Those were pivotal moments when I decided to go into education to help students understand Earth Science.

Those moments back in college helped me rethink my understanding and daily practice of the three R’s (reduce, reuse, and recycle) after I graduated from college. I became a vegetarian, started shopping at thrift stores, and began adjusting my thermostat to save electricity. In the last few years I have added to that list of environmental practices by biking to work when I can, cutting down on purchasing plastic products, and buying local and sustainable food.

These activities became so important to me that they are now a part of my daily life. These actions are ones that I consider normal but others may think of these actions as more expensive, time consuming, or taking too much effort to complete. The public needs to be more educated on the importance of living a sustainable lifestyle and what could happen if they do not. Making simple choices in their homes about using less water and electricity are great places to start. As a teacher, I was able to help students make more sustainable choices at school.

I taught eighth grade earth science for five years. Throughout those five years, I learned that students, and even my fellow teachers, had a lot to learn about the environment and how to care for it. At my last school, where I taught for three years, I really enjoyed working on the green initiatives that were happening on campus. Another teacher and I helped a group of students plan and implement a school garden that would eventually bring in produce for the cafeteria. That same group of students also helped our school strengthen its recycling program. They added signs to all of the bins (showing what materials belonged where), made two videos to show the student body how to recycle properly, and implemented Terracycle, an upcycling program that earned money for our school. These activities got me excited to go to work for a couple of reasons: the students were in charge of these changes and these were activities that I would have loved to be a part of when I was in school.

Besides the green initiatives on campus, I also enjoyed writing lesson plans for my students. Planning the content each day and how I was going to deliver it to the students was exciting for me. How could I make learning about rocks and minerals fun for eighth grade students? How would the lesson flow to keep them interested? These were just some of the questions I asked myself while lesson planning.

During those five years as a teacher, I planned many lessons for my Earth Science class, as well as an elective classes that I taught. Planning lessons was more enjoyable than the delivery of the lesson. I really liked the behind the scenes part of the process. Searching the internet for lesson plans or creating new lessons from scratch were both practices that I did on a regular basis. Teaching about the environment combined my joy of the environment and lesson planning.

Two important environmental topics that I taught in the past were water quality and air pollution. While trying to incorporate environmental topics into my lessons, I struggled with finding exciting, organized lessons that were interdisciplinary and aligned with multiple Minnesota K-12 Academic Standards in Science. Many of the activities and lessons did not have enough exploration or explored environmental issues in a negative light. I needed some help to find the right resources for my students.

In the summer of 2013, I attended the Summer Institute for Climate Change Education put on by Climate Generation: A Will Steger Legacy (Climate Generation), formerly the Will Steger Foundation. During those three days, I was introduced to the educational resources that Climate Generation offered and the best practices for teaching about climate change. Over 60 educators and I learned about climate change and the solutions our students could be a part of. This conference helped me see the importance of educating our young people about the repercussions of climate change, and more importantly, the solutions they could engage in.

The Summer Institute also helped me advance my environmental teaching at school to more than just recycling and to include the ever important topic of climate change. I was very impressed with Climate Generation's curricula suite, as it explained climate change in a way that made sense for my students. The curricula suite did not explain climate change in a negative way. Climate change repercussions were discussed, but each curriculum ended with solutions that students could engage in. It was a positive way to close out a heavy topic.

The data and activities in Climate Generation's curricula suite were well presented and the solutions at the end of each curricula were well placed. Middle school students can handle a certain amount of negative information regarding climate change, but they need to know what they can do to help the problem. The solutions need to be thoughtful and the activities need to end on a positive note. 'Doom and gloom' lessons make the students want to give up and not make changes for the better.

Climate Generation made such a lasting impression on me that I applied for an internship they posted the next year. Making the decision that classroom teaching was not where I was meant to be was pretty easy at that point. I was also continuing to engage in more environmentally-minded tasks in my daily life: bringing my own mug every time I got coffee, buying a hybrid car, and composting my food waste. All of these things are necessary to combat climate change. Unfortunately, most people do not understand the connections that those actions have to climate change. Helping people make those connections was, and still is, very important to me.

After quitting my job as a classroom teacher, I moved into my new position as an intern at Climate Generation. Climate Generation had a curricula suite of five published curricula on climate change and energy education when I started my internship and I got the opportunity to edit and update them all with new data and graphics. Aligning the curricula to the newest Minnesota science, language arts, and social studies standards was also part of my job. Each curriculum that I edited and updated included a section showing how the content aligned with the NGSS as well. There were lists showing the performance expectations, crosscutting concepts, science and engineering practices, and disciplinary core ideas that were covered in each lesson. The problem was that the entire curricula suite was written before the NGSS came out. We fit the NGSS into the curriculum, rather than making the curriculum fit the NGSS.

During this work, I realized that I could help educators without being in front of the classroom. I missed planning lessons for a classroom, but I could do it behind the scenes, writing a curriculum about the science of climate change. I wanted to create a curriculum that used the NGSS as the backbone for the lessons. The lessons should be shaped around the outcomes of the NGSS. Teachers need to have curriculum that is multi-purpose and fits multiple standards in their subject area. Having a lesson be interdisciplinary can help as well. When a science and social studies teacher can team up and teach a topic from different angles, more learning can take place. I was excited to use the NGSS to make a new climate change curriculum that does all of that.

Climate Change Curriculum

Children can start to get environmental education lessons at home: turning off lights when leaving a room, playing outside, or recycling. If parents do not understand the concepts or the benefits of environmental education, however, that education will not take place until children are in school. Using the NGSS is a great way to make a connection between students, their families, and their teachers. Several reports, Taking Science to School (2007), Ready, Set, SCIENCE! (2008), A Framework for K-12 Science Education (2012), consistently cite that students from diverse backgrounds do very well in science when their opportunities for leaning are equal to their peers (NGSS Lead States, 2013). The NGSS even advocate for parent involvement in the school via field trips, homework assignments, and surveys.

The connection that the NGSS make to the student's home life is important. The need to connect families and parents to the classroom is vital. Teachers need to partner with families in order to solicit their help with homework and increase participation in science-related events at school (NGSS Lead States, 2013, pg. 32). Homework assignments can also include joint participation with parents to increase at home completion and encourage discussion between students and parents.

State and national educational standards are important to ensure students get a quality education regardless of what school they attend. According to the Minnesota Department of Education (n.d.), "Districts are required to put state standards into place so all students have access to high-quality content and instruction." For teachers, standards can seem like a long list of items to get through in a short window of time each year. For students, they are a crucial piece of their education. I created a curriculum that is aligned with science standards, easy for educators to implement, and exciting for students to engage with.

Many young people are interested in climate change. This was quite apparent at the People's Climate March in New York City on September 21, 2014 when 50,000 college students marched to show the world that climate change is real and solutions need to happen (People's Climate, n.d.). These students need quality resources and dedicated teachers to teach them about climate change. The public must understand that their collective actions are related to what is happening to the environment. The recent extreme weather events, sea level rise, and melting ice caps are happening because of increased greenhouse gases in the atmosphere. Climate change is happening because of choices that we have all made as a society. The repercussions of climate change are not one person's fault, which is why it will be difficult to fix. The good news, is that once we accept that humans are the main cause, and that we need to work together to solve the problem, momentum should pick up. This is one main reason that I wrote this curriculum: an overwhelming desire to educate today's youth.

The NGSS came out in 2013. At the publication of this capstone, seventeen states and the District of Columbia had adopted the standards. Because the NGSS are new, lessons need to be created for teachers now, so they can transition to using the standards as quickly as possible. As more states adopt the NGSS, the need for quality curriculum will only increase. I hope this new curriculum will also serve as a template for others to create more in the future. I hope the knowledge that I gain in doing this project will help me assist other organizations or individuals with their work with the NGSS.

Project Mission

This project will tackle the problem of the lack of climate change curricula, or curricula in general, that utilizes the NGSS as a framework. The project, a curriculum called *Next Generation Climate*, includes a detailed process of how to write a curriculum using the NGSS as a guide and template, as well as provides a climate change curriculum that can be used in a middle school setting.

The research that went into *Next Generation Climate* includes literature that was written by the states that produced the NGSS. Research also included reading papers and articles from scientists and teachers that made, or are using, the NGSS. Chapter two summarizes those resources in a literature review. This includes research on how the NGSS were created, the role experiential education plays in the curriculum, the importance of climate literacy, a summary of the NGSS, and methods for writing a curriculum.

This curriculum has the potential to be used by hundreds of teachers and seen by thousands of students because it is accessible on the Climate Generation website to download. I created a climate change curriculum that educators are excited to use and that can be shared with people around the country and even the world. I hope that this project accomplishes not only the creation of new educational climate change material, but also provides a deep understanding of the environment and climate change.

CHAPTER TWO

Literature Review

The purpose of this capstone was to create a climate change curriculum that utilizes the NGSS as a framework. The curriculum created for this capstone, *Next Generation Climate*, uses the NGSS as a framework and these standards will guide each lesson. The topic of *Next Generation Climate* is climate change and students will understand and find evidence to support the question: how do we know the global temperature is rising, among other questions. The science of climate change is important for students to understand (as they are the future decision makers of the world), and the NGSS are the first national science standards to include anthropogenic (human-induced) climate change. This inclusion of climate change is the reason the NGSS make sense to frame *Next Generation Climate*. This chapter will focus on five main topics: climate change science and literacy, experiential education, an explanation of the NGSS and why they are important, and methods used to write a middle school science curriculum.

The National Science Teachers Association (2014) offers a compelling reason for each state to adopt and use the NGSS. "The U.S. has a leaky K–12 STEM talent pipeline… We need new science standards that stimulate and build interest in STEM" (para. 1). Science, technology, engineering, and math are all important topics for students. The NGSS will better prepare our high school graduates for college and the careers that follow by requiring "students operate at the intersection of practice, content, and connection" (NGSS Lead States, 2013, p. xvi). This intersection and the rigorous content reflects how science is conducted in the real world.

This chapter will focus on understanding the NGSS and other topics related to climate change and middle school science curriculum writing. The first section, Change Change and the Importance of Climate Literacy, will discuss the important climate change topics that are featured the final curriculum and the importance of being climate literate. Understanding why climate literacy is important will help the reader see why *Next Generation Climate* was created and the pressing need for a climate literate society.

The second section will be a discussion on experiential education and why it was used in the curriculum. Examples of experiential education are included, as well as a discussion about how experiential learning goes beyond hands-on activities.

Section three, The Road to the NGSS, will help the reader understand why and how the the NGSS were created and why they are important. These standards are unlike other science standards that have been written, and this section will help the reader understand the reason why the NGSS were chosen to write *Next Generation Climate*.

Because this curriculum is written using the NGSS as a framework, an understanding of how the standards are organized will be included next. This will involve diving into the many parts of the NGSS and understanding them separately as well as together. This section will break down the parts of the NGSS to explain how to use them in the classroom and explain why they are a natural progression as science standards.

The final section of chapter two will discuss using the NGSS to write a middle school curriculum as well as include other models of curriculum development. Methods to Write Curriculum will focus on the models that will be used to write the curriculum, as well as current research regarding the appropriate methods to teach students about climate change in science and social studies classrooms. Together, these sections will illustrate the literature that assisted in writing *Next Generation Climate*.

Change Change and the Importance of Climate Literacy

The *Next Generation Climate* curriculum will educate students on the science and repercussions of the rise of the global temperature and uses the NGSS performance expectations to guide each lesson. Because of this, a considerable amount of time was spent doing research about what students need to know about climate change and how best to teach them. These strategies and topics could be identified as effective climate change education pedagogy. This section will explore important data about climate change, the importance of quality communication about climate change, and what students need to know to be climate-literate. The term global warming will not be used in this capstone. Climate change will be used instead. The terms can be used interchangeably. Climate change has become a more common term because repercussions include more than just a change in temperature.

When discussing climate change, it is important to grasp what people should understand about the topic. A climate-literate person:

> understands the essential principles of Earth's climate system, knows how to assess scientifically credible information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions with regard to actions that may affect climate (U.S. Global Change Research Program, 2009).

Why does climate literacy matter? There are many reasons for making sure the population is climate literate and understands how and why the world is changing. Those reasons include the climatic changes as well as the specific human impacts: the global temperature has increased 0.6 degrees celsius during the 20th century, observations and models indicate humans are the main cause of the temperature increase, and increases in economic and environmental challenges will continue to exacerbate hardships for citizens of the world (U.S. Global Change Research Program, 2009).

Understanding the science of climate change and how many weather and climate related problems the world is experiencing are because of humans influence on the environment, is imperative to fixing the problem. The biggest positive that comes from being climate literate is that humans have the knowledge to take actions to reduce climate change and its repercussions. By understanding the Essential Principles of Climate Science (Table 1), citizens will be able to make informed decisions about the environment and their lives (U.S. Global Change Research Program, 2009).

Table 1:

Climate Literacy Principles
The Sun is the primary source of energy for Earth's climate system.
Climate is regulated by complex interactions among components of the Earth system.
Life on Earth depends on, is shaped by, and affects climate.
Climate varies over space and time through both natural and man-made processes.
Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
Human activities are impacting the climate system.
Climate change will have consequences for the Earth system and human lives.

Climate literacy, or climate education, needs to be happening in schools across the country. However, according to a recent article published in Science Magazine (2016), there is a lot of confusion being presented to middle and high school students about climate change, if it is included in the curriculum at all. Plutzer, et al. (2016) describe how they organized the first nationally representative survey of science teachers focused on climate change. Of the 1500 middle and high school teachers that completed the survey, seventy five percent teach about global warming for at least an hour during the school year. Although it is not a lot of time, the problem lies with the way that climate change is presented to students. Mixed messages come from thirty percent of teachers when they explain that current warming is natural or from the twelve percent of teachers that do not explain the cause of climate change to be from humans at all (Plutzer, et al., 2016).

There has been a lot of information presented about the repercussions of climate change: the global temperatures are rising at unprecedented rates, the sea ice in the Arctic is melting, and areas of the United States are experiencing multi-year droughts. With all of this negative news, it is no wonder that students struggle to find hope, engage in learning, or even care about the issue. Students may feel defeated before educators even finish a lesson. In an Introduction to Environmental Studies class at the University of Arizona, the professor noticed this defeated attitude with the students in the class. The focus of the class was on how humans were altering the planet: deforestation, climate change, and lack of positive policy changes to name a few topics. In an article that Liverman (2014) wrote for *The Washington Post*, the professor explains that this technique was not working. The problem was that the students were just getting depressed about the situation. The professor was trying to "shock them out of complacency and into action," but the opposite was happening (Liverman, 2014). The way climate change is communicated is a very important factor in how the information gets absorbed by the audience.

It is important to present climate change information in a way that appeals to students. In an article for the publication *Reports of The National Center for Science Education*, C. St. John (2013) explains what teaching about climate change should look like:

> ...for climate science information to be absorbed by audiences, it must be actively communicated with appropriate language, analogy and metaphor; combined with narrative storytelling; made vivid through visual imagery and experiential scenarios; balanced with scientific information; and delivered by trusted messengers in group settings (p. 15).

Combining these teaching methods with quality data will help students understand and relate to the science of climate change. This will hopefully lead to feelings of empowerment to create change, live healthier lives, and talk to others to help the climate change movement forward. For Liverman (2014), a change of narrative was needed for the Introduction to Environmental Studies class. Rather than focusing on the negative aspects of the environment (what was not being done or how negatively humans were impacting the landscape), the professor discussed the United States policy wins and the influential people that have done great environmental work around the world (Aldo

Leopold, Rachel Carson) (Liverman, 2014). This new way of looking at the environment changed the student's perspectives and helped them see hope for the future.

Communication plays a large role in getting students to participate in the solutions to climate change. St. John's article, "Climate Change Adaptation: Lessons from Unlikely Sources," explains how to help people rise to the challenge of climate change solutions. St. John (2013) states that "clearly communicating the benefits of action and the downsides of inaction can contribute toward a robust solution…" (p. 15). The benefits of climate change actions could include renewable energy job creation, cleaner air and water, and/or the peace of mind that one's grandchildren will grow up in a world that is without major flooding and droughts. While the downsides of inaction could include increased extreme weather events, a rise in energy created from fossil fuels, or water pollution from fracking and other fossil fuel extraction practices.

In a TedX event at the University of Montana, S. Hassol (2015) lists three ways that climate change information should be communicated: climate change should be presented in simple, clear messages that use plain language, they should be repeated often, and communicated using stories, because stories are memorable. These climate change communication techniques can easily be used with students in middle and high school. Encourage students to ask questions when they arise. Students also need time to practice. Ideas in the classroom need to be introduced and students need time to understand them in many different ways, from various angles, possibly in the form of stories. After they have had sufficient time to practice, and have heard the topics repeated many times, they can be assessed.

The three methods presented by S. Hassol are almost mirror images of the ones presented by C. St. John. Climate change communication and education needs to be clear and appropriate, repeated and practiced, and involve the telling of stories. These are all significant ways to teach middle school students about climate change. Unfortunately, educators may encounter students (and parents) that are not accepting of the science of climate change.

Climate change is the one of the most urgent threats to the human species. According the President Obama, "…there's one issue that will define the contours of this century more dramatically than any other, and that is the urgent and growing threat of a changing climate" (The White House, 2014). Children and young adults that are alive right now are the first generation to be living with the effects of climate change, and they are the ones who will, hopefully, find solutions. And yet, there are still many people that are denying that humans are the cause of our changing climate. Because of this, decreasing this country's fossil fuel consumption and consumeristic lifestyle (two major shifts that need to happen to slow the effects of climate change) are not happening fast enough. Unfortunately, human activities like our use of fossil fuels and our overconsumption of stuff are not affecting this planet at a slow rate.

There are many ways that humans are altering this planet. Wysession (2013) lists some of these negative changes in an article for *Science Scope*: humans use about forty percent of Earth's land surface for agriculture, our roads and parking lots in the United States take up an area equal to the state of Georgia, and ocean acidity has increased thirty percent in just a few centuries (p.18). These are all topics that can be taught in an Earth

Science classroom, but could also benefit from the integration with other areas of science and even other subject areas. According to Wysession (2013), the best earth and space science teaching will take place when all of the sciences [physical, life, earth, chemistry] are well integrated.

Not only is it important for the sciences to be well integrated when teaching about climate change, an interdisciplinary education will also help students become climate literate. According to the U.S. Global Change Research Program (2009), climate change is an ideal topic for interdisciplinary teaching. The *Climate Literacy: The Essential Principles of Climate Science* document describes ways to educate about climate change in an interdisciplinary way: recording weather and comparing it with historical climate data, assessing the ways that climate change is affecting human health, and calculating the affects climate change has on the economy (U.S. Global Change, 2009). Not only will students learn the science of climate change, they will also see the importance of behavior change and climate action.

Providing a link between student's behavior and actions is important in any environmental education lesson, including those related to climate change. A research project done at San Jose State University helped show how beneficial that connection can be. Cordero, Todd, & Abellera (2007) began by stating that decisions to protect the environment will only come from an educated population. The purpose of their project was to "determine the effect of action-oriented learning on climate change literacy" (p. 866). This project was completed with college students enrolled in a meteorology course.

Before a 15-week course on weather and climate, students that had enrolled in a meteorology course took a questionnaire about their knowledge of climate science. Then, half of the class was given an assignment to complete an ecological footprint quiz online, the other half did not participate in this assignment. A footprint quiz asks questions about the participant's daily behaviors related to energy use, transportation, consumerism, diet, and waste production.

Based on the results from another questionnaire at the end of the course, students that took the ecological footprint quiz had a better understanding of global warming causes. According to Cordero et al. (2007), "the...activity appears to help students connect products and personal actions with energy use and global warming (p. 869)." Many students were "shocked" at their results of the ecological footprint activity. Cordero et al. (2007) states that the activity actually helped some students connect their lifestyle choices with the effects of global warming. If an ecological footprint quiz could help undergraduate students connect their actions to the repercussions of climate change, it could help middle school students also make the same connections or help them think about their daily actions.

As was stated before, this research was done with college students, but the main idea can be translated to middle school students. Using action learning models (ecological footprint activity) and making personal connections between students and climate change will result in positive climate change education (Cordero et al., 2007). This could happen in many different classes or subject areas.

Often climate change is taught in the science classroom. Because of the many social issues surrounding the impacts of climate change, it could also be taught in the social studies classroom. Two concepts about climate change solutions that are often discussed, and would fit within a social studies curriculum, are mitigation and adaptation.

Mitigation refers to human interventions to reduce the sources of greenhouse gases or enhance the sinks that remove them from the atmosphere (U.S. Global Change Research Program, 2009). Examples of mitigation include: expanding mass transit systems, using a solar thermal hot water system, and creating more park land. Adaptation refers to initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects (U.S. Global Change Research Program, 2009). Examples of adaptation include upgrading sewer systems, installing high tunnels to protect farmer's crops, and offering indoor activities for students during the hot summer months.

There are a number of activities about mitigation and adaptation that educators could use to illustrate the concepts, which will be discussed in the next two paragraphs, and again in Chapter 3: Curriculum Outline. Teachers could facilitate a healthy discussion or debate about which is the best, or a better option as a solution to climate change. Kumler & Vosburg (2014) discuss ways that climate change, and the topics of mitigation and adaptation can be included in the social studies classroom. In the article, "Climate Change in the Social Studies Classroom: A Why and How-to Guide Using the C3 Framework" a list of questions is included that could be asked as part of any social studies class. Some of those questions include: what role does the government have in climate change mitigation and adaptation, what role do citizens have in climate change mitigation and adaption, and how can climate change be addressed on the local, regional, and global level? (Kumler & Vosburg, 2014). These questions could also be a part of a science discussion and could lead to an exciting action project using other scientific climate change resources.

A robust resource for anyone wanting information about climate change repercussions around the United States is the National Climate Assessment (NCA). The NCA report was produced with the assistance of a 60-member Federal Advisory Committee and over 300 experts, as well as reviews from the public and a number of scientists (National Climate Assessment, 2014). The National Climate Assessment gives very detailed information about the repercussions that each area of the United States will experience. The NCA website summarizes the impacts the United States will endure because of climate change for each region of the United States. According to the National Climate Assessment (2014), the midwest region of the United States is experiencing impacts to agriculture, a change in forest composition, and increased risks to the Great Lakes. Students can use the website to find repercussions that other regions of the United States are experiencing.

The importance of a climate literate population is vital to solving the problem of climate change. Even though there is great climate change educational pedagogy, there are still shortcomings. Teachers need to communicate to their students that climate change is human-induced and lessons need to be solutions-based to help students have hope for their future. When students become climate literate they will be able to communicate in a meaningful way and be able to make informed decisions about how their actions affect the climate. These lessons can take place in a social studies classroom, but very often are taught in science classes, using hands-on activities that get students to reflect on what they learn.

Experiential Learning

A philosophy that was used in the creation of this curriculum is experiential learning or experiential education. The idea of experiential learning can be traced back to the fifth century with the following ancient Chinese proverb: I hear, and I forget; I see, and I remember; I do, and I understand. When students have the opportunity to practice what they are learning, with a hands-on activity, they internalize the knowledge and better understand the concept. Science standards should also reflect how science is done in the real world, and that is best shown by hands-on activities. But experiential education is more than just hands-on activities; reflection and application are also integral parts of this learning process.

If the goal of learning is to only transfer knowledge (which gas is most prevalent in the atmosphere), the best way to do this would be to tell the person directly. However, if the goal of learning is to be able to apply the learned information to a new situation, experiential education is a better approach ("Why Use," n.d.). For example, understanding what is happening in the atmosphere that leads to the greenhouse effect. Students are able to accomplish this by being actively engaged throughout the entire learning process in several ways: constructing meaning about what they are learning, assuming responsibility of their learning, and posing questions throughout the process (Experiential Learning, n.d.). These are just part of a long list of experiential learning principles that Northern Illinois University (n.d.) put together in their Experiential Learning document. Other experiential learning principles include: the personalization of learning, the learning that is taking place is authentic and real, and the design of the learning experience includes learning from mistakes and successes (Experiential Learning, n.d.). These are all qualities of good experiential education.

Experiential eduction is more than just a hands-on activity or experience. Students must experience a progression of three components: doing the activity, reflecting about the activity, and the application to new situations. The student must first take part in a concrete experience, action, or activity. This component on its own is just hands-on learning. When coupled with reflection and application, experiential education takes place. The reflection stage happens when students share reactions and observations in a discussion and analysis time (“Why Use,” n.d.). This is so important for students as it gives them a chance to process what happened during the activity. Finally, students need to deepen their understanding of the situation in the application phase. By applying what they learned to a new situation or activity, students are able to use what they learned in a new setting (“Why Use,” n.d.). This is truly what science looks like in the real world.

At the Illinois Mathematics and Science Academy (ISMA), a program was developed to engage fourth and fifth grade students in experiential education. This program, IMSA Fusion, uses real world science and engineering to help students learn science and math concepts. For example, students in a fourth grade science class, studied ways to block cell phone transmission by building Faraday cages to understand how radio waves travel (Kolar, Phillips, Kolar, 2014). As long as there is time for reflection and analysis, experiential education takes place. A topic where students benefit from using experiential education is climate change. The possibilities for hands-on activities, reflection, and application are great.

Experiential education is a concept that should be familiar to science educators. Using activities that include an experience, reflection, and application is important to help students understand how science is done in the real world. Several states have adopted new science standards that mirror how science is done and were created using the most current research on scientific learning.

The Road to the Next Generation Science Standards

The Next Generation Science Standards were created based on the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Framework)* that came out in 2011. The *Framework* provided "the most current research on science and scientific learning, and it identifie[d] the science that all K-12 student should know" and was the first step in creating the NGSS (NGSS Lead States, 2013, p. xiv). The NGSS website (2013d) describes the *Framework* as having a vision based on an understanding of science that "...[is both] a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge" (para. 1). The *Framework* was the main document that was used to create the NGSS. It is important to note that the *Framework* is not a set of standards, but rather the most current research about teaching science.

Along with the National Research Council, the other lead partners of the NGSS included: the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve. The National Research Council developed the *Framework*, the National Science Teachers Association and the American Association for the Advancement of Science provided advice to the project and engaged the scientific community in providing important feedback, and Achieve coordinated the second phase — development of the NGSS on behalf of the lead states (NGSS Lead States, n.d.).

Phase two of the creation of the NGSS included identifying lead states and writers to write the actual standards and provide feedback. This eighty-person group worked for two years, with the help of scientists, educators, and the public, to create a set of science standards that integrated the three dimensions of the *Framework* (NGSS Lead States, 2013c). The three dimensions that form each standard are: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. This integration made the NGSS very different from previous science standards, where every standard stood on its own.

The *Framework* identified the most current research in the four science disciplinary areas: life sciences; physical sciences; earth and space sciences; and engineering, technology and the applications of science (National Academies, 2011). The disciplinary core ideas come out of each science area. Within each disciplinary area, the framework also identifies seven crosscutting concepts and eight scientific and engineering practices that should always be taught in context with the core ideas. Together, these three ‘threads’ become part of a braid. These braids become the standards or performance expectations of the NGSS; the concepts that students need to understand and demonstrate by the end of the unit. All three of these dimensions, as well as the performance expectations, will be discussed further in the section titled Next Generation Science Standards.

Writers of the *Framework* also had to figure out how educators could teach the content in a way that allowed for real application of student knowledge. According to the article, “What Research Says About K-8 Science Learning and Teaching” (2008), major changes to curriculum in grades K-8 are necessary to improve science education (Duschl, Shouse, & Schweingruber). In this article, a recommendation is made to teach science in a progression that will help students develop scientific knowledge across grade levels and units of study (Duschl, Shouse, & Schweingruber, 2008). A main goal of both the *Framework* and the NGSS is to provide a way of learning that current standards and educational approaches are not able to do:

> ...ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science, the capacity to discuss and think critically about science-related issues, and the skills to pursue careers in science or engineering if they want to do so… (National Academies, 2011, para. 3).

The NGSS offer the opportunity to not only improve science education in this country, but also student achievement. They are a set of national science standards that are redefining science education across the country. Current science standards, those that are not the NGSS, around the country do not provide the context for students to succeed. Standards that were used before the NGSS were adopted in Kansas failed to link rigorous content with scientific and engineering practices (NGSS Lead States, 2013, pg. 18). This can clearly be seen in the following biology standard: “The student understands organisms vary widely within and between populations. Variation allows for natural selection to occur” (NGSS Lead States, 2013, pg. 19). If you compare that standard with an NGSS, you will see the way core ideas (variation and traits) are linked with scientific practices (constructing explanations): “Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population” (NGSS Lead States, 2013, pg. 19). This integration of core ideas, scientific practices, and crosscutting concepts make the NGSS different from other standards.

The fact that the NGSS are student performance expectations, not curriculum, also make them different from other standards. These performance expectations clarify the outcomes for students by stating what students will be able to know and do by the end of a unit or grade level. However, they are not so specific that they say how the learning should happen. There is flexibility in how educators explain the content and how their students express their understanding during an assessment.

Another way the NGSS are different from previous science standards is the focus on applying practices to content knowledge, not separating them as unconnected ideas (NGSS Lead States, 2013, p. 1). The NGSS uses the *Framework’s* three dimensions to create standards that illustrate a broader understanding of science. The NGSS put equal weight on practice, crosscutting concepts, and core ideas.

Finally, the integration of technology and engineering throughout the NGSS is not necessarily unique to these standards, but raises the importance of engineering design to the same level as scientific inquiry (NGSS Lead States, 2013, p. 3). This important shift in the NGSS happened for two important reasons: to ensure our young people have the skills to address major world engineering problems in the future (clean energy, maintaining supplies of clean water) and to deepen their understanding of science (NGSS Lead States, 2013, p. 3).

The structure and purpose of the NGSS make them different from other science standards. These standards provide students with the outcomes they need to understand content using three dimensional learning. The NGSS are a great framework for creating a climate change curriculum.

Next Generation Science Standards

Each dimension of the NGSS (practices, crosscutting concepts, and disciplinary core ideas) is broken down to give the reader a better understanding of how educators can use the NGSS to help their students achieve mastery of science. The dimensions are woven together and a discussion about the performance expectations will follow after the three dimensions. This discussion of the NGSS will happen through the lens of earth science and, more specifically, climate change.

It was mentioned earlier that the NGSS are the first national science standards that include human-induced climate change. It is important to note that the NGSS, as pointed out by Wysession (2013), do not pass moral judgement on the human activities that are discussed in the disciplinary core ideas and performance expectations. Rather than blame humans for the changes that have happened, “The impacts are simply the reality of the immense power of our species and need to be recognized as such in our educational standards” (Wysession, 2013, p. 18). This is not meant to downplay the fact that the NGSS make it clear that climate change is anthropogenic, it just means that humans need to understand that climate change is a big problem and we need to make changes to solve the problem. The NGSS do this by using phrases like “reducing human vulnerability” and “understanding human behavior and applying that knowledge wisely in decisions…” (NGSS Lead States, 2013, p. 240). The NGSS also invite students to use the science and engineering practices: argumentation and questioning to help them understand how human activities affect the environment.

Science and engineering practices. The science and engineering practices refer to the “behaviors that scientists engage in as they investigate and build models” (NGSS Lead States, 2013d, para. 2). These could have been called “skills,” but the word “practices” emphasizes the need for knowledge, as well as skills to participate in investigations within the science classroom. There are eight practices that the NGSS use to engage students in the practices of science to make their learning more meaningful.

Modeling is a key science and engineering practice from the NGSS. A model, in science, represents a system and could be shown as a diagram, analogy, computer simulation, or a physical replica (NGSS Lead States, 2013, p. 52). An example of a system that could be represented as a model when studying climate change is the atmosphere. Students need to understand that models have limitations, and simplifying the atmosphere into a concise model would make it easier to understand what is happening. According to the NGSS (NGSS Lead States, 2013), by the time students get to middle school they need to be able to develop or use a model to describe phenomena and even unobservable mechanisms (p. 53).

A specific concept that would benefit from modeling when teaching climate change is the greenhouse effect. It is a tricky concept for students to understand because they have no way of seeing how molecules in the atmosphere behave. By using a model, like the one presented by Kaufman (2013), students are actively engaged in experiential education and are able to see an unobservable process with their own eyes. In the Carbon Dioxide Game, students act out the process of the greenhouse effect, are able to show how heat is trapped in the atmosphere naturally, and can see how humans alter the greenhouse effect to cause additional, unnatural warming (Kaufman, 2013). Educators could expand on this model by asking students to draw their understanding of the greenhouse effect after participating in the game, further helping students understand the concept and showing them another type of model.

Another scientific and engineering practice that can be used when teaching climate change is engaging in argument from evidence. Scientific argument is an important part of climate change education. When the NGSS use the word, “argument,” they are referring to “a process for reaching agreements about explanations…” (NGSS Lead States, 2013, p. 62). According to the NGSS Lead States (2013), Performance Expectation MS-ESS3-4 states that by the end of middle school, students need to “construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems” (p. 241). Climate change is happening in part because of our consumption of natural resources and the human population’s impact on the world. Both of these activities require mass amounts of energy, which releases carbon dioxide and other greenhouse gases into the air.

In a detailed article for Science Scope Magazine, B. Golden and colleagues write about an activity titled, “Generating Arguments about Climate Change” that presents students with facts about climate change and information about how to engage in argumentation. This activity aligns with the performance expectation mentioned in the previous paragraph, but this one activity would not be enough to allow students to be assessed. Students would need more practice in engaging in argumentation before an assessment.

In the activity “Generating Arguments about Climate Change,” students are given a collection of data (graphs, pictures, tables) from multiple sources. In small groups, over several class periods, students were asked to use the data collection to generate an argument that addresses a guiding question (“Is the Earth presently cooling, warming, or staying the same?” and “What are some potential causes of climate change?”) (Golden et al., 2012). Students spent time exploring the collection of data, then explained and shared their argument with the class. In order to address another scientific and engineering practices (obtaining, evaluating, and communicating information), students were able to create posters or individually written essays to explain the global and local implications of climate change (Golden et al., 2012).

This activity is notable because it allowed students to explore a complex set of data, work with a small group to generate an argument based on evidence, and communicate their work to a large group. The problem with this activity was the practice of having students discuss if global warming, i.e. climate change, is happening or not. This is not a debate or discussion that students should be having, as scientists have already established that climate change is happening. K. Poppleton, Director of Education at Climate Generation, states that debating about the existence of climate change is bad practice and will lead to misconceptions for students. Scientists have already established that climate change is real and human-induced (personal communication, May 1, 2016). The discussion for this activity should center around answering the questions ‘Why is Earth warming?’ and ‘What are the repercussions of that warming?’ None the less, there are still valuable aspects of this activity.

The activity “Generating Arguments about Climate Change” was written before the NGSS were created, but can still be used to support the new science standards. The science and engineering practices are just one dimension of the NGSS. When students use science and engineering practices, they are not isolated from other parts of the NGSS. If students are engaging in argumentation (a science and engineering practice), they are often looking for patterns within a data source or a cause and effect relationship between various impacts. Patterns and cause and effect are examples of crosscutting concepts.

Crosscutting concepts. Crosscutting concepts are the links that connect all disciplinary areas of science together (life, earth and space, physical, and nature of science and engineering). The seven crosscutting concepts are: patterns; cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; and stability and change. According to the NGSS website (2013d), when these concepts are made explicit to students, they provide a way for students to organize information across the scientific disciplines. It is recommended that these concepts be introduced early in schooling to give students repetition in different contexts that will build their familiarity from kindergarten to graduation (NGSS Lead States, 2013, p. 80).

In an article written for Science Scope, M. Wysession (2013) describes crosscutting concepts as “universal principles (e.g. cause and effect, system models) that apply to all sciences” (p. 18). This means they can and should be taught in all science classes and at all grade levels. The seven crosscutting concepts are meant to help students deepen their understanding of the core ideas being taught (NGSS Lead States, 2013, p. 79).

Each crosscutting concepts increases in complexity across grade levels (NGSS Lead States, 2013, p. 81). This helps students become familiar with common vocabulary and understand the concepts in different contexts throughout their science education. An example of the pattern crosscutting concept at difference grade levels is as follows: first grade students use observations of the sun to describe patterns, and high school students construct an explanation for the outcome of a chemical reaction while understanding the patterns of chemical properties (NGSS Lead States, 2013, p. 82). These two examples come from different science disciplines, astronomy and chemistry. From each science discipline, there are several core ideas, or topics that students will learn.

Disciplinary core ideas. Disciplinary core ideas are the focusing ideas for K-12 science education. As stated on the NGSS website, disciplinary core ideas are used to drive curriculum, instruction and assessment (2013d). Looking back at the *Framework*, the NGSS used the following three explanations to build and choose the disciplinary core ideas. First, the disciplinary core ideas (just like the crosscutting concepts) are built on a learning progression that starts in Kindergarten and continues until grade twelve. Students are given the ability to revise their knowledge as the scientific concepts around them change and get more complex. Second, there are a limited number of disciplinary core ideas to allow students to explore the subject content in greater depth. Lastly, knowledge must be paired with practice in science education experiences (NGSS Lead States, 2013, p. 40). This is why disciplinary core ideas are never taught in isolation — they are always taught with at least one crosscutting concept and scientific and engineering practice, to create connectedness between the three dimensions.

There are two disciplinary core ideas that align directly with climate change: Human Impacts on Earth Systems and Global Climate Change. The Human Impacts disciplinary core ideas, as described by Wysession (2013), "primarily focuse[s] on how human technology is affecting Earth's other systems and how that same technology can also be used to monitor, understand, and minimize these impacts" (p. 20). Wysession (2013) continues by discussing the importance of Earth and Space Science standards in the NGSS:

> ...human interactions is the primary reason for the increased attention given to Earth and Space science in the NGSS. [This big idea] contains many of the most

> newsworthy topics in science: natural hazards, energy sources, water and mineral availability, climate change, environmental impacts, and human sustainability (p. 19).

Students may see more of these newsworthy topics as they become more frequent and disrupt families around the world. This is yet another reason why the NGSS should be implemented in every state to ensure students understand the implications of climate change.

Performance Expectations. Together, these three dimensions (science and engineering practices, disciplinary core ideas, and crosscutting concepts) are used to create the performance expectations for the NGSS. The performance expectations are statements that explain what students should be able to do at the end of a lesson or unit. They are not a set of instructional tasks. Each performance expectation incorporates at least one of each of the three dimensions of the *Framework* (NGSS Lead States, 2013, pg. xxii).

There is a lot of information contained in each performance expectation. Each performance expectation is written in detail, along with a clarification statement, which gives the educator examples of the content to be taught. Below each statement is a group of colored rectangles. The colors blue, orange, and green, correspond to the scientific and engineering practices, disciplinary core idea, and crosscutting concepts, respectively. The table below illustrates the performance expectation: Earth and Human Activity MS-ESS3-4 (NGSS lead states, 2013b) and includes the science and engineering practices, disciplinary core ideas, and crosscutting concepts that correspond.

Table 2: Earth and Human Activity Performance Expectation MS-ESS3-4

Students who demonstrate understanding can:

MS-ESS3-4. **Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.** [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	**ESS3.C: Human Impacts on Earth Systems** • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. - - - - - - - - - - ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. - - - - - - - - - - ***Connections to Nature of Science*** **Science Addresses Questions About the Natural and Material World** • Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

One important aspect about the NGSS is the cohesiveness that is built upon while learning. A student should not be assessed on their ability to define a particular crosscutting concept or science practice (NGSS Lead States, 2013, p. 80). Once they have found connections and have built a robust understanding of a particular core idea, with help from the science and engineering practices and crosscutting concepts, can they be assessed, in accordance with the performance expectation.

The NGSS are complex, but once each of the three dimensions are dissected, there is real learning that takes place in the classroom. The complexity and interconnectedness of the NGSS combine to produce a set of standards that will intensify the learning in any science classroom. Because of their inclusion of anthropogenic climate change, the NGSS are an obvious choice to use in writing a detailed climate change curriculum. The next section will discuss the current literature about writing curriculum for middle school students.

Methods to Write Curriculum

Writing a curriculum requires one to create and follow a process. There are many curriculum models that can be used to design a set of lessons. In this section, the methods that were used to write the *Next Generation Climate* curriculum will be discussed. This section will also include discussions of methods that are useful when teaching about science and climate change to ensure maximum understanding of the topic.

Without a plan or template, writing a curriculum could be confusing for the author and later for the reader. Some people start the planning process by using a set of standards as their framework. A curriculum planning tool that is often used when starting with specific academic standards is the Understanding by Design (UbD) method. This method is often chosen because it allows the author to start with standards, big ideas, and essential questions of the unit or curriculum, before thinking about activities and assessments. The other important part of Understanding by Design is the order in which planning is done. Teachers can start with the desired results and work “backwards” to transfer standards into big ideas and learning targets (McTighe, n.d.). Rather than designing a curriculum around specific activities, UbD starts with the essential ideas that students must know and builds in the actives and assessments later in the process. The NGSS could be a starting point for the UbD method.

In *UbD in a Nutshell*, McTighe (n.d.) puts forth a method for thinking purposefully about writing and planning a lesson or curriculum. Understanding by Design is the right tool for planning a climate change curriculum because it emphasizes the importance of students being able to transfer their learning to real-world situations (McTighe, n.d.). The NGSS have students practice scientific behaviors and Understanding by Design mirrors that by having students perform what they learned. This could be in the form of explanation, application, or self-assessment. This allows the understanding to be applied to new situations and shows the teacher how the learning was transferred.

Understanding by Design does not inform the curriculum writer exactly how to organize a lesson or curriculum, but rather it is a set of helpful design tools (McTighe, n.d.). This means that certain parts of each stage can be left out or altered without losing the integrity of the design method. The three stages of Understanding by Design are: Desired Results, Assessment Evidence, and creating the Learning Plan. Each stage of the design process helps the author create a meaningful and cohesive lesson or curriculum that helps students make sense of the "big ideas" and allows them to transfer their learning to real world situations (McTighe, n.d.).

Stage one of Understanding by Design (Desired Results) asks educators to think of the essential questions and the goals or educational standards the design will address (Wiggins, 2009). These are the big ideas of the curriculum. Beyond the standards or big ideas that students will need to address, educators should frame these essential questions in statements that begin "students will be able to…" (McTighe, n.d.). This will help students see from the beginning what they will be expected to know or be able to do at the end of the lesson. This stage is important for the students so they know what is expected of them from the very beginning of the lesson.

Assessment Evidence, or stage 2 of Understanding by Design, invites educators to come up with the tasks that students will perform to show their understanding of the topic and under what criteria students will be judged (Wiggins, 2009). These tasks could include quizzes, journal prompts, observations, reflections, or other activities. These are the activities or tasks when students would prove what they have learned. However, students would need to do more than just answer a few questions. The students should be able to transfer their knowledge to new situations and explain or interpret their learning (Wiggins, 2009). McTighe (n.d.) explains the framework that stage 2 uses to create assessment tasks. The Six Facets of Understanding is featured in Table 3 and makes suggestions for teachers to find ways to vary how students can apply their knowledge to new situations.

Table 3:

The 6 Facets of Understanding:
• **Explain**: the student generalizes, makes connections, has a sound theory, can put in their own words
• **Interpret**: the student offers a plausible and supported account of text, data, experience
• **Apply**: the student can transfer, adapt, adjust, address novel issues & problems
• **Perspective**: the student can see from different points of view
• **Empathy**: the student can walk in the shoes of people/characters
• **Self-understanding**: the student can self-assess, see the limits of their understanding, reflect

The final stage of Understanding by Design, creating the Learning Plan, puts what and how is being taught into a plan that makes logical sense (McTighe, n.d.). When creating the learning plan, it is best to use the acronym, WHERETO. The elements and their meanings are illustrated in Table 4. This set of elements will help educators assess the learning plan (Wiggins, 2009). McTighe (n.d.) emphasizes that when putting the learning plan together it is important to use the most appropriate resources for students, not just the textbook. These resources could include educational websites, news articles, or scientific data and graphs.

Table 4:

WHERETO:
Where: ensuring that the student sees the big picture, has answers to the "Why?" questions, knows the final performance expectations as soon as possible
Hook: immersing the student immediately in the ideas and issues of the unit, engaging the student in thought-provoking experiences
Equip & Experience: providing the student with the tools, resources, skill, and information needed to achieve the desired understandings; and successfully accomplish the performance tasks
Rethink: enhance understanding by shifting perspective, considering different theories, challenging prior assumptions, introducing new evidence and ideas, etc.
Evaluate: ensuring that students get diagnostic and formative feedback, and opportunities to self-assess and self-adjust
Tailor: Personalize the learning through differentiated instruction, assignments and assessments without sacrificing validity or rigor
Organize: Sequence the work to suit the understanding goals (e.g., questioning the flow provided by the textbook, which is typically organized around discrete topics)

The use of Understanding by Design is a helpful way to create a cohesive and meaningful lesson or curriculum for students. When combined and aligned with other organizational tools, like standards, the curriculum can become very robust.

Using the NGSS as a framework for a curriculum or using it to guide a lesson, provides a lot of scaffolding. In an article for Science Scope, K. Mesmer (2015) explains the process of a school district adopting the NGSS and where to start when implementing these science standards into new or previously used lessons. Mesmer (2015) captures the essence of the NGSS by explaining that students are doing science by using science and engineering practices which is reflective of real life. This was an important change that this district science coach noticed during the implementation of the NGSS. Mesmer (2015) states "students are doing science, not just learning the end result of scientific research (p. 20). This engagement in science practices is such an important part of the NGSS.

Argumentation is one of the science and engineering practices that make up the NGSS and is a healthy way for students to find and interpret important information in their research. During the argumentation process, students need a template in order to effectively create solid arguments with real evidence. McNeill and Martin (2011), developed a framework to help students communicate their arguments in a practical way. This framework, commonly called Claim, Evidence, and Reasoning (CER), allows students to build their claims and engage in productive argumentation. Students begin by writing out their claim; a statement that answers a question or problem (McNeill, K. & Martin, D., 2011, p. 53). This is followed by collecting evidence that supports the claim (either in first hand investigations or research) and then providing the reasoning or justification for why the evidence they supplied supports their claim (McNeill, K. & Martin, D., 2011). This part of the CER framework could be done in a science class, but could work also in other classes. A Language Arts class would be a great way to make the learning more interdisciplinary and allow students to concentrate on speaking or writing skills as it relates the argumentation and climate change.

Kumler & Vosburg-Bluem (2014) wrote an informative article on implementing climate change education into a social studies classroom using the C3 Framework (national social studies standards). The C3 Framework has many similarities to the Next Generation Science Standards. Looking at the organization of the C3 Framework, as seen in Table 5, one can see several aspects in each dimension that are also seen in the NGSS. Developing questions, making claims and using evidence, and communicating conclusions are just a few of the similarities (Kumler & Vosburg-Bluem, 2014, p. 226). This is yet another reason why interdisciplinary teaching of climate change, or any topic that uses both the C3 Framework and the NGSS as a guide, makes sense for students.

Table 5: Organization of the C3 Framework

Dimension 1: Developing Questions and Planning Inquiries	**Dimension 2: Applying Disciplinary Tools and Concepts**	**Dimension 3: Evaluating Sources and Using Evidence**	**Dimension 4: Communicating Conclusions and Taking Informed Action**
Developing Questions and Planning Inquiries	Civics	Gathering and Evaluating Sources	Communicating and Critiquing Conclusions
	Economics	Developing Claims and Using Evidence	Taking Informed Action
	Geography		
	History		

Because of the unintended political nature of climate change and the work that is taking place at local, state, and national levels, social studies is an exciting and unique place to engage students in climate change education (Kumler & Vosburg-Bluem, 2014, p. 226). Teachers could use any social studies class (history, civics, geography, economics) to facilitate discussions, engage in activities related to climate change, and discuss specific concepts.

Conclusion

Creating a climate change curriculum that utilizes the NGSS as a framework is the purpose of this capstone. Chapter two sifted through the literature that has been written on topics that are related to climate change, experiential education, the NGSS, and methods for writing a curriculum. Understanding these topics will give the reader an appreciation for the climate change curriculum that has been written. Chapter three will discuss the methods that were used to write the *Next Generation Climate* curriculum.

CHAPTER THREE

Methods

The purpose of this capstone was to create a middle school climate change curriculum that utilizes the NGSS as a framework. The methods in this chapter will discuss the timeline and parameters that were used to write the *Next Generation Climate* curriculum, as well as the outline of *Next Generation Climate* and reasons for its development. These topics will be broken up into three sections: Curriculum Logistics, Curriculum Development Process, and Curriculum Outline.

The first section, Curriculum Logistics, will be a discussion about what content to include when writing a curriculum about climate change. The next two sections, Curriculum Development Process and Curriculum Outline explain the details of writing *Next Generation Climate*. The Curriculum Development Process section is very important to understanding the flow of the curriculum and will help others write their own curriculum in the future. The outline of the curriculum will help the reader understand what the final curriculum looks like and will include an explanation of why specific activities and ideas were included.

Curriculum Logistics

When writing a new curriculum, or even daily lesson plans, it helps to find a topic that is exciting to write about. This will ensure that the writer will be fully engaged in the writing process and do a quality job in relaying the information. *Next Generation Climate* was written because of the author’s deep passion for climate change and an important call to action to create quality educational resources for teachers and young people. Educating youth about the science of climate change and the solutions they can be a part of is important to curb the almost inevitable repercussions.

Next Generation Climate is intended to be used with middle school students, grades six through eight. This grade level was chosen because the performance expectations that include climate change for middle school work well together and the author's previous experience teaching middle school students. The Earth and Space Science performance expectations that were chosen have a specific connection to climate change. The performance expectations are from the Earth and Human Activity standard and will provide a robust education of climate change.

The way this curriculum will be organized requires that the performance expectations be overlapped throughout the lessons. Teachers will be able to introduce a concept early in the curriculum, let the students practice (once or twice), and then assess their gained knowledge towards the end of the curriculum.

I have chosen to focus on designing a six-lesson curriculum for educators to use in classrooms and other informal educational settings. Many teachers do not have time to insert extra lessons or new material into their already packed school year. K. Poppleton explains why six lessons is a good fit for educators. "The six-lesson curriculum model that we use at Climate Generation is based on our evaluation results from leading our Summer Institute for Climate Change Education for ten years. Teachers prefer modules that they can use over a short period of time verses a full semester curriculum" (personal communication, May 1, 2016).

Creating a curriculum that can be used completely or as stand-alone lessons will also make it easier for teachers to use *Next Generation Climate*. If taught in its entirety, this curriculum should take approximately two weeks. In this time, three performance expectations will be addressed. This is an appropriate number of standards to tackle in two weeks. If there were more, students would not have time to practice and learn the content before they were assessed. If there were less than three, students could get bored. Climate change resources are plentiful, but ones that focus on the NGSS are only recently being created. I hope I can be on the cutting edge of resources for science educators around the country.

The most current science was used throughout the entire. This includes graphs and maps, the work of current scientists, and activities from other teachers and organizations. The purpose of using resources that have already been created is to save time but also to use the robust, quality work that educators have already created.

The NGSS are national science standards. Because of that, *Next Generation Climate* will be able to be used in any state in the United States, with potential to be used internationally. There will be many opportunities in this curriculum for educators to personalize the lessons to their state or geographic region. With the use of the National Climate Assessment report and website, educators can use the sections that pertain to their state. This will help the students relate to the content as it will feel local and close to home.

Curriculum Development Process

Next Generation Climate was designed using the Understanding by Design (UbD) method of curriculum development. The reason this method was chosen was because UbD states that any curriculum or unit designer starts with the essential questions and long-term goals and designs the curriculum backward. There are specific goals (an understanding of how the average global temperature is changing) and standards (the Next Generation Science Standards) that this curriculum was framed around. Using the three steps of the Understanding by Design process (as discussed in Chapter 2), six meaningful lessons were created that translate important climate change knowledge to middle school students.

Development for this curriculum, and stage one of the Understanding by Design process, began by addressing the desired results of the curriculum. In other words, what were the major goals and big ideas that students needed to understand at the end of the curriculum or lesson? For *Next Generation Climate*, the big ideas came from the NGSS. After deciding to use the NGSS, the next step was to choose the standards that the curriculum would be framed around. As any teacher knows, standards are what guide the content that is taught in the classroom. For social studies teachers, that might be the C3 Framework for Social Studies State Standards. For English Language Arts or Math teachers, they would maybe chose the Common Core standards for their respective subject. The *Next Generation Climate* curriculum uses the NGSS. These standards were chosen for three reasons: they are the first national science standards to include anthropogenic (human-induced) climate change, multiple states have adopted them as their science standards, and teachers in those states need resources that are aligned to the NGSS.

The performance expectations that this curriculum focuses on contain the knowledge and skills that students need to acquire. Three performance expectations were chosen to provide the big ideas. These performance expectations are the statements that describe what each student should be able to do at the end of the unit. Through a series of activities, readings, and discussions, students will build an understanding of each performance expectation. The three performance expectations used in *Next Generation Climate* are:

1. MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
2. MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
3. MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's system.

The curriculum development process involved a lot of research about how to properly teach about climate change. In an article in *Reports of The National Center for Science Education*, C. St. John (2013) explains what this should look like:

> ...for climate science information to be absorbed by audiences, it must be actively communicated with appropriate language, analogy and metaphor; combines with narrative storytelling; made vivid through visual imagery and experiential

> scenarios' balanced with scientific information' and delivered by trusted messengers in group settings (p. 15)

The methods of teaching listed above: appropriate language, analogies, storytelling, and visual imagery, were used in *Next Generation Climate* to teach climate change in an experiential way. Other resources used during the research and brainstorming phases were books and websites about the NGSS and articles written about teaching climate change.

Stage two of the UbD process involved creating essential questions that students would explore. Those questions were then used to develop authentic performance tasks that students would demonstrate. The list of essential questions for each lesson will be presented in the next section, Curriculum Outline. Thinking about other ways students will demonstrate their knowledge is also part of stage two, as well as allowing time for student reflection.

A variety of assessment tools were used throughout *Next Generation Climate*. The assessment for each performance expectation, are be as follows:

1. For the first performance expectation (MS-ESS3-5), students will be asked to write entries in a science notebook or journal. Students will also complete a mini research project using the National Climate Assessment website. They will research a specific region on the United States and what repercussions that region will experience because of climate change.
2. The second performance expectation (MS-ESS3-3) asks students to design a method for monitoring and minimizing a human impact on the environment.

Students will be asked to use the engineering design process to complete their detailed design.

3. For the final performance expectation (MS-ESS3-4), students will be introduced to the Claim, Evidence, Reasoning method of constructing an argument in lesson two and will be able to practice. Then in lesson five, students will construct an argument about the best mitigation and adaptation options to reduce the repercussions of climate change. Students will engage in a class discussion about the positive and negative repercussions they have researched.

Because the performance expectations do not coincide with a particular lesson, these activities will happen at different places throughout the six lesson curriculum. When designing a lesson plan, or an entire curriculum, it is important to give students time to practice before they are assessed. It is also helpful to present the information in difference forms. For example, Lesson 2 of *Next Generation Climate* presents the greenhouse effect to students in the form of a game, an analogy, and a set of graphs and data.

It is important to understand the process of creating essential questions and choosing the types of evidence that students will engage in to demonstrate the knowledge they gained during the unit. In Lesson 3 of *Next Generation Climate,* students need to recognize the repercussions of the rise in global temperature. I chose to use the National Climate Assessment (NCA) to give students a robust resource to see the repercussions of climate change from around the United States. The NCA site also provided most of the graphs, maps, and other pictures for other lessons of this curriculum. One of the performance expectations for this lesson has students ask questions to clarify evidence of the factors that have caused the rise in global temperatures. From this, the student learning outcome (essential question) became “students will be able to explain the repercussions of climate change using the National Climate Assessment.”

In Lesson 3, there are also opportunities for students to journal, an important part of the curriculum that helps students reflect on their learning and generate new ideas. The two main pieces of evidence that show student understanding of the essential questions, are the NCA research project and a final journal entry. The journal entry is a graphic that students create that shows what they learned about the repercussions of climate change. Each of the other five lessons were designed in the same way.

The final stage of the UbD process allows educators to create a learning plan. The learning plan includes activities and experiences that will lead to achievement at the end of the unit. This is also where the unit is organized. A few of the activities are listed in the next section, Curriculum Outline.

When organizing the Learning Plan, I used the WHERETO acronym to help guide each lesson, as explained in The Methods to Write Curriculum section of Chapter 2. Using Lesson 3 as the example, I want to explain how each part of the acronym WHERETO plays a role in the learning plan.

Students need to know *where* the lesson is going. It is important to start out with an essential question or student learning outcome. This statement begins “Students will be able to…” and helps students know what they are expected to do at the end of the lesson, in kid-friendly language. For lesson three the learning outcome is “students will be able to explain several repercussions of climate change where they live using the National Climate Assessment, among other resources." Once students know where they are going, they need to be hooked. The *hook* is the first part of the lesson that grabs the student's attention and gets them interested in the topic. Lesson three starts off with an activity that gets students out of their seats and walking around the room. They are looking at signs that are posted around the room that show the "Ten Indicators of a Warming World" and writing about what evidence (indicators of climate change) they have seen in their lives.

Teachers need to help students *experience* and *explore* the issues during the lessons. This step can include any number of activities, games, readings, worksheets, or labs. Anything that gives students experiences with the topic at hand. The activity in lesson three is the National Climate Assessment Research Project. Students need time to *rethink* and *revise* their understanding of their work, as well as *evaluate* their work when they are finished. As part of the student's research project in lesson three, students are asked questions regarding the information they found about climate change and how it is impacting their region. Students also need to think about how the problems can be addressed. To finish the activity, students need to evaluate their research and put it together in a short speech or video.

The final two steps of the learning plan process of WHERETO are to *tailor*, or personalize, the content and be *organized* during the lesson. These two steps are ones that the teacher is responsible for implementing. It depends on his or her students as to how personalization of the content is addressed.

Each lesson in the *Next Generation Climate* curriculum used the same steps (WHERETO) when putting together the Learning Plan. In addition, background information was written for each lesson to help the teacher have a brief but thorough understanding of the content before teaching the lesson. The beginning of each lesson also includes a list of materials, vocabulary, tasks for educators to prepare before teaching, time estimates to complete each lesson, and the performance expectations that are addressed in the lesson.

The lessons of this curriculum were subject to many rounds of editing. This included checking the flow of the lesson to be sure it could be implemented easily into the classroom, being sure all vocabulary in the lesson was properly defined, and the ever important spelling and grammar checks. This curriculum took approximately ten months to write, edit, and publish.

Curriculum Outline

Next Generation Climate is a six-lesson, interdisciplinary climate change curriculum that utilizes the NGSS as a framework. Each lesson builds on the previous and many topics are introduced early in the unit and then revisited again towards the end. However, the individual lessons of this curriculum will be able to stand alone as a single lesson, and not have to be used with the rest of the curriculum. The following outline lists each of the lesson's essential questions and what students will accomplish in each lesson.

1. **What evidence is there to show there is a rise in global temperature?** In this lesson students are introduced to evidence that shows there has been a rise in

global temperature over the past century. Students will engage in activities around developing good clarifying questions and discuss what makes good scientific evidence.

2. **What factors have caused the rise in global temperature over the last century?** In this lesson students will distinguish between human activities and natural processes and investigate the greenhouse effect. Students will construct an argument about the cause of the global temperature rise and use current data, including graphs and maps, to support their argument.
3. **What are the repercussions of the rise in global temperature?** In this lesson students will discover how temperatures impact their region through research using the National Climate Assessment. Students will also be able to explain what makes a good scientific resource.
4. **What would you need to monitor the repercussions of the rise in global temperature?** In this lesson students will research how to monitor the repercussions of climate change. Students will learn about citizen science and get the opportunity to participate in a project.
5. **In what ways can the repercussions of climate change be minimized?** In this lesson students will investigate the terms adaptation and mitigation, by researching and then debating the best options for minimizing human impacts on the climate using the same argumentation tool from Lesson 2.

6. **How can you design a method for monitoring and minimizing climate change?** In this lesson students will use the engineering design process to create a way to minimize and monitor human impact on the environment.

Conclusion

This curriculum features three performance expectations from the Next Generation Science Standards. Using the NGSS and the design method, Understanding by Design, created an organized, interdisciplinary, science-based middle school curriculum that teaches students about climate change and the rise in global temperature. Students will complete a number of activities, readings, and discussions that lead to an understanding of the rise in global temperature and the repercussions that the United States is experiencing because of that temperature rise. This capstone was not implemented into a classroom or other educational setting by the author.

Next Generation Climate is featured on the Climate Generation website. It is free for educators around the world to download. This curriculum has been presented to educators at national and state educational workshops and conferences. It will continue to be a focus for Climate Generation in the future. Chapter four will feature a six-lesson curriculum for middle school students on climate change; its causes, repercussions, and solutions: *Next Generation Climate* for grades 6-8.

CHAPTER FOUR

Next Generation Climate Curriculum overview

While the entire curriculum is available in Appendix A, this chapter contains the basic structure of content for *Next Generation Climate*. Chapter four includes the Next Generation Science Standards that were used to write the curriculum, the Lesson Organizer, and the first page of each lesson. To see *Next Generation Climate* in its entirety, please see Appendix A.

Next Generation Climate

Grades 6-8

Next Generation Science Standards (NGSS)

In 2013, the NGSS were released as the most current, research- based way of educating students in STEM and preparing them for STEM careers. The NGSS establishes high standards for delivering effective STEM education. They challenge us to provide the instructional support in our curriculum resources and to make NGSS accessible to educators in the classroom. Hands on learning, effective communication, making connections across all domains of science and other disciplines, an emphasis on including "all voices," and the importance of developing a learning progression are not only integral to the NGSS, but have always guided Climate Generation's development of educational resources.

NGSS performance expectations represent the final assessment of learning and therefore cannot fully develop a student's full mastery. Additionally, true NGSS instruction and learning is three dimensional- including not only core ideas (CI), but cross cutting concepts (CCC) and scientific and engineering practices (SEP) as well. Lesson plans that best support NGSS performance expectations, CI, CC and SEP are listed below.

Middle School Next Generation Science Standards	*Lesson 1*	*Lesson 2*	*Lesson 3*	*Lesson 4*	*Lesson 5*	*Lesson 6*
Human Impacts						
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.				•		•
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.		•			•	
Weather and Climate						
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century	•	•	•	•	•	
Engineering Design						
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.						•
Physical Science Disciplinary Core Ideas						
PS4B - Electromagnetic Radiation		•				•
Earth & Space Science Disciplinary Core Ideas						
ESS2D - Weather & Climate	•					
ESS3C - Human Impacts on Earth Systems		•	•	•	•	•
ESS3D - Global Climate Change	•	•	•	•	•	•
Engineering, Technology & Applications of Science Disciplinary Core Ideas						
ETS1B - Developing Possible Solutions				•	•	•
ETS1C - Optimizing the Design Solution						•

NGSS (cont.)

Middle School Next Generation Science Standards	*Lesson 1*	*Lesson 2*	*Lesson 3*	*Lesson 4*	*Lesson 5*	*Lesson 6*
Cross Cutting Concepts						
1. Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	·	·		·		
2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	·	·	·	·	·	·
3. Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.	·				·	
4. Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.		·				·
5. Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.		·				
7. Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	·	·	·	·		
Science and Engineering Practices						
1. Asking questions (for science) and defining problems (for engineering).	·	·	·	·	·	
2. Developing and using models	·	·			·	
3. Planning and carrying out investigations						·
4. Analyzing and interpreting data						·
6. Constructing explanations (for science) and designing solutions (for engineering)			·	·		·
7. Engaging in argument from evidence		·			·	
8. Obtaining, evaluating, and communicating information		·	·	·	·	·

Lesson Outcomes	Lesson Materials
Lesson 1: What evidence is there to show there is a rise in global temperature?	
• Students will be able to make conclusions about global temperature using various indicators as evidence. • Students will be able to ask questions that clarify evidence. • Students will be able to distinguish between weather and climate.	Global Land and Ocean Temperature Anomalies graph Lesson 1 Worksheet: Temperature Indicators Temperature Indicators Figure Set Temperature Indicators Figure Set Descriptions
Lesson 2: What factors have caused the rise in global temperature over the last century?	
• Students will be able to construct an argument, compare and critique multiple arguments, and analyze or interpret the facts presented. • Students will be able to investigate how temperature increase impacts and changes the atmospheric conditions. • Students will be able to demonstrate the greenhouse effect by showing how carbon dioxide and other greenhouse gases in the atmosphere trap heat and insulate the Earth. • Students will be able to determine how human population increase and per-capita consumption are contributing to the rise in global temperature and the concentration of greenhouse gases in the atmosphere. • Students will be able to distinguish between the greenhouse effect and climate change.	Human Impact Cards Lesson 2 Worksheet 1: Claim, Evidence, Reasoning Evidence Figure Set Evidence Figure Set Descriptions Lesson 2 Worksheet 2: Discussion Diamond Separating Human and Natural Influences on Climate figure
Lesson 3: What are the repercussions of the rise in global temperature?	
• Students will be able to explain several repercussions of climate change where they live using the National Climate Assessment, among other resources. • Students will be able to explain what makes a good scientific resource.	Ten Indicators of a Warming World graphic Lesson 3 Worksheet 1: Climate Change Repercussions Research Project Lesson 3 Worksheet 2: National Climate Assessment Scavenger Hunt National Climate Assessment Scavenger Hunt Answer Key
Lesson 4: What would you need to monitor the repercussions of the rise in global temperature?	
• Students will be able to describe how scientists are monitoring the repercussions of climate change. • Students will be able to explain what citizen science is and be able to participate in a citizen science project.	Lesson 4 Worksheet: Scientists in Action Scientist Stories Citizen Science slideshow
Lesson 5: In what ways can the repercussions of climate change be minimized?	
• Students will be able to explain the difference between adaptation and mitigation, and provide many examples of each. • Students will be able to debate about the positives and negatives of mitigation and adaptation solutions using the CER framework.	Impacts, Mitigation, and Adaptation Prompt Lines Mitigation and Adaptation Venn Diagram Lesson 5 Worksheet 1: Adaptation and Mitigation Scenarios Lesson 5 Worksheet 2: Claim, Evidence, Reasoning (Mitigation and Adaptation)
Lesson 6: How can you design a method for monitoring and minimizing climate change?	
• Students will be able to use the engineering design process to create a way to monitor and minimize human impact on the environment.	

Age Level	Grades 6-8
Time Needed	Two 50 minutes class periods
Materials	Global Land and Ocean Temperature Anomalies graph Worksheet: Temperature Indicators Temperature Indicators figure set (1 set of 12 for class) Temperature Indicators figure set Descriptions (if using) Science journal for each student
Vocabulary	**indicator:** a sign that shows the condition or existence of something (factors). **weather:** the atmospheric conditions of a specific place at a specific point in time. **climate:** the weather conditions over a given time interval (months, years). **trend:** A general tendency or course of events: a warming trend. **climate change:** a change in the typical or average weather of a region or city. This could be a change in a region's average annual rainfall, or it could be a change in a city's average temperature for a given month or season. **anomaly:** a deviation from the common rule (exception).
Student Learning Outcomes	• Students will be able to make conclusions about global temperature using various indicators as evidence. • Students will be able to ask questions that clarify evidence. • Students will be able to distinguish between weather and climate.
Performace Expectation(s) addressed	**MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Print each page of the Global Land and Ocean Temperature Anomalies graph. • Print a classroom set of the Temperature Indicators figure set and Temperature Indicators Figure Set Descriptions (if using) • Make copies of Temperature Indicators worksheet for each student. • Students will need a science journal for these lessons. Make journals with students during class or use composition notebooks. Journals will make great summative assessments at the end of the six lessons or to use as formative assessments throughout the unit. • Before beginning this lesson, have students go home and interview an older relative about weather and climate. Students should ask their relative about what they remember about the weather when they were younger. They will share their stories with the class. • Consult the Questioning Guide in the front of this curriculum for detailed structure on questioning and how to elicit good questioning.

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods
Materials	Human Impact cards (1 set) Lesson 2 Worksheet 1: Claim, Evidence, Reasoning (1 for each student) Evidence Figure Set (1 set of 10 per group) Evidence Figure Set Descriptions (1 set) Lesson 2 Worksheet 2: Discussion Diamond (1 for each student) Separating Human and Natural Influences on Climate figure A large open area and chalk Small bag labeled 'What do humans do?'
Vocabulary	**greenhouse effect:** A phenomenon in which the atmosphere of a planet traps radiation emitted by its sun, caused by gases such as carbon dioxide, water vapor, and methane that allow incoming sunlight to pass through but retain heat radiated back from the planet's surface. **greenhouse gas:** gases which allow direct sunlight to reach Earth's surface, but absorb the infrared energy (heat) that is reradiated to the atmosphere. These gases include: water vapor, carbon dioxide, methane, nitrous oxide, among others. Also referred to as heat-trapping gases. **cumulative:** increasing or increased in quantity **atmosphere:** the mixture of gases that surrounds earth; the air **carbon dioxide:** CO_2, is the primary greenhouse gas emitted through human activities **emissions:** the act of producing or sending out something (such as energy or gas) from a source **carbon sink:** anything that absorbs more carbon that it releases (trees, ocean)
Student Learning Outcomes	• Students will be able to construct an argument, compare and critique multiple arguments, and analyze or interpret the facts presented. • Students will be able to investigate how temperature increase impacts and changes the atmospheric conditions. • Students will be able to demonstrate the greenhouse effect by showing how carbon dioxide and other greenhouse gases in the atmosphere trap heat and insulate the Earth. • Students will be able to determine how human population increase and per-capita consumption are contributing to the rise in the global temperature and the concentration of greenhouse gases in the atmosphere. • Students will be able to distinguish between the greenhouse effect and climate change.
Performace Expectation(s) addressed	**MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's system. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	**Greenhouse Effect Game:** • Print *Human Impacts Cards* and create 'What do humans do?' bag. • Find a large, open area for game play, preferably outside. Draw two concentric circles on the ground, one about 4 feet in diameter, and a larger one about 30 feet in diameter. The smaller circle represents the Earth and the larger one represents Earth's atmosphere. • Read the information about CER (Claim, Evidence, Reasoning) in the beginning of the curriculum guide. This will provide you will an understanding of how to implement and assess this form of argumentation. • Make copies of the *Evidence Figures and Evidence Figure Set Descriptions (if using)* for each group. • Make copies of the *Lesson 2 Activity: Claim, Evidence, Reasoning* worksheet for each student. • Make copies of the *Discussion Diamond* Worksheet for each student.

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods (2 days if presentations are skipped)
Materials	Ten Indicators of A Warming World graphic Climate Change Repercussions Research Project (1 for each student) National Climate Assessment Scavenger Hunt (1 for each student) Student computers or access to ipads or tablets
Vocabulary	repercussion: an unintended consequence occurring some time after an event or action, especially an unwelcome one (i.e. impacts)
Student Learning Outcomes	• Students will be able to explain several repercussions of climate change where they live using the National Climate Assessment, among other resources. • Students will be able to explain what makes a good scientific resource.
Performace Expectation(s) addressed	**MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Become familiar with the National Climate Assessment site before introducing it to your students. • Make copies of the Climate Change Repercussions Research Project worksheet for each student. • Make 1 sign for each of the Ten Indicators of A Warming World graphic and post around the room.

Background Information

Lesson 2 showed students that scientists are highly confident that many of these observed changes can be linked to the climbing levels of carbon dioxide and other greenhouse gases in our atmosphere, which are caused by human activities.

The National Climate Assessment (NCA) is an informational resource describing the impacts of climate change. It is a report that summarizes the impacts of climate change for the United States, now and in the future. Hundreds of experts, guided by members of the Federal Advisory Committee, produced the report, which was extensively reviewed by the public and experts, including the National Academy of Sciences. The report was turned into a website that will be used extensively in this lesson and in Lesson 5.

For educators that would like suggestions about how to use the National Climate Assessment in the classroom, visit this site: https://www.climate.gov/teaching/2014-national-climate-assessment-resources-educators. This site features a list of all key messages and guiding questions for every region in the US as well as links to other resources outside of the NCA.

In Lesson 2, students explored the many factors that are causing global temperatures to rise. Population increase, more agriculture activity, and the production of cement are just a few pieces of the puzzle. With all of these factors causing global temperatures to rise, it is just a matter of time before we start seeing the repercussions of those actions, indeed some of the repercussions are already being felt around the world.

Age Level	Grades 6-8
Time Needed	Two 50 minute class periods
Materials	Scientists in Action worksheet (1 for each student) Scientist Stories (1 classroom set) Citizen Science slideshow Citizen Science equipment (if needed)
Vocabulary	**citizen science:** Public volunteers of all ages assisting scientists in their research **resilience:** Capacity to recover quickly from difficulties, toughness (Resilience comes from having the capacity to respond to change.)
Student Learning Outcomes	• Students will be able to describe how scientists are monitoring the repercussions of climate change. • Students will be able to explain what citizen science is and be able to participate in a citizen science project.
Performace Expectation(s) addressed	**MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Make copies of the Scientists in Action worksheet for each student. • Make a classroom set of the Scientist Stories. Make 6 'scientist stations' around the classroom. Students will visit each station to learn about the scientist and answer questions on their worksheet. • Before doing the Citizen Science Activity, familiarize yourself with several citizen science examples. Choose one that you could participate in with your students, or let your students decide which one they would like to participate in. Sign up before the start of the lesson and, if possible, obtain the necessary tools to allow your students to begin collecting information right away.

Background Information

At this point students have learned that there is an ongoing rise of the global temperature and about the repercussions that are happening because of that rise. In this lesson, students will learn how scientists monitor the repercussions of climate change and how they can also participate in monitoring.

It is important to monitor the repercussions of climate change, because only if we know the impacts will we able to plan for the future and develop methods to minimize them. For example, monitoring the population of certain trees is crucial because their health impacts many species including other trees, insects, and animals. In Minnesota, aspen and tamarack trees are dying from changes in precipitation patterns, temperature fluctuations, and insect defoliation. Being able to monitor these changes is crucial to understanding what needs to be done to help save these species.

Emphasize to students that in order to monitor these repercussions, it takes time. Point out that while monitoring, scientists are looking for trends. As we discussed in earlier lessons, long term trends cannot be determined from just a few years, more time is needed to fully understand what and how things are happening in nature.

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods
Materials	Impacts, Mitigation, Adaptation Prompt Lines (1 for class) Mitigation and Adaptation Venn Diagram Worksheet: Adaptation & Mitigation Scenarios (1 for each student) Worksheet: Claim, Evidence, Reasoning (Mitigation and Adaptation) (1 for each student)
Vocabulary	**mitigation:** Technology changes that reduce emissions, reduces or prevents greenhouse gas emissions. **adaptation:** Adjustment in natural or human systems to a new or changing environment that moderates negative effects, reduces harm to the environment. **resilience:** The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.
Student Learning Outcomes	• Students will be able to explain the difference between adaptation and mitigation, and provide many examples of each. • Students will be able to debate about the positives and negatives of mitigation and adaptation solutions using the CER framework.
Performace Expectation(s) addressed	MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's system. MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Make one copy of *Impacts, Mitigation, Adaptation Prompt Lines.* • Make copies of *Adaptation & Mitigation Scenarios* worksheet for each student. • Make copies of *Claim, Evidence, Reasoning (Mitigation and Adaptation)* worksheet for each student. • Create and post two signs on opposite walls in your classroom. Signs will say "Impacts of Climate Change" and "Actions to Combat Climate Change" and will be used for the Impacts, Mitigation, and Adaptation Activity.

Background Information

Students will apply the information they learned in Lesson 2 about making claims in this lesson. They will research and discuss/debate the many ways of minimizing the effects of climate change. Refer to the CER discussion in the front of this curriculum for more information (page vi and vii).

There are many terms that are used when discussing climate change solutions. Making students aware of the terms and differences between them is important to their understanding of solutions. Mitigation is often used when discussing possible solutions. *Mitigation* involves reducing the severity or seriousness of a problem. We can mitigate the effects of climate change by creating more fuel efficient vehicles or using renewable energy. *Adaptation* means adjusting to new conditions. This means that the effects are already occurring. While mitigation is concerned with reducing future effects, adaption is taking action on the current issues at hand, recognizing that they are already occurring. We can adapt to a changing climate by making upgrades to sewer systems for increased rainfall during storms. These actions will lead to more resilient communities therefore allowing those communities to recover quicker from the repercussions of climate change.

Lesson 6: How can you design a method for monitoring and minimizing climate change?

Your solution to minimize a climate change

Age Level	Grades 6-8
Time Needed	Two 50 minute class periods (plus more time outside class for data collection)
Vocabulary	**engineering:** The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.
Student Learning Outcomes	• Students will be able to use the engineering design process to create a way to monitor and minimize climate change.
Performance Expectation(s) addressed	**MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
Educator Prep	• Some student ideas may need approval from your principal or superintendent. Be prepared to ask for permission or limit the actions that your students can take in this lesson.

Background Information

In this lesson students will use the process of engineering design to create a way to minimize and monitor climate change. For this activity we consider a simple outline of the engineering process (there are many):

a. Define the problem and resources available
b. Brainstorm solutions
c. Develop a plan
d. Test your plan
e. Improve the plan
f. Analyze the plan and use it

As the educator, you have the choice to limit this creation to something the students create in the classroom, regarding just themselves, or extend their reach out into the world. They could create a plan to monitor and minimize something in their house, at their school, or across their state. It could be a real project or one that is so big that it can only be conceptualized.

> *We can reduce the risks we will face from climate change. By making choices that reduce greenhouse gas pollution, and preparing for the changes that are already underway, we can reduce risks from climate change. Our decisions today will shape the world our children and grandchildren will live in.*
>
> *- Environmental Protection Agency*

Here are a few examples:

- Monitor idling cars at the end of the school day. Make a plan to help minimize the number of cars/buses that are waiting to pick kids by creating no-idling zones.
- Monitor the amount of rain water runoff around school. Create a plan to minimize rainwater runoff and wasted water by installing a rain garden.
- Monitor the amount of food waste at lunch. Make a plan to minimize that waste by implementing a compost system.

CHAPTER FIVE

Conclusion

Writing this climate change curriculum for middle school students utilizing the Next Generation Science Standards as a framework was successful in many ways. The end product, *Next Generation Climate*, is a science-based, interdisciplinary resource for middle school educators to use with their students to help them understand why the global temperature is rising and the repercussions the world is experiencing because of it. Siting back and thinking about *Next Generation Climate,* I reflect on learning about and using the NGSS, what I discovered about myself and curriculum writing as a whole and also about what is next for me in this research.

The NGSS are a great way to frame a climate change curriculum. The standards are specific and create a deep understanding of science that today's youth need. They are the first national science standards that include human-induced climate change and made the initial organization of *Next Generation Climate* come together quite easily. When writing your own curriculum, if the NGSS are not the standards that are chosen, another set of standards will work just as well. The important thing to remember is to keep coming back to the standard to keep the curriculum focused.

Personally, I feel that the NGSS are the standards that all states should adopt as their own. The only problem I find with this, and with the NGSS in general, is the limited number of disciplinary core ideas that are covered. This was done to ensure deep understanding of the core ideas present, but could cause states to miss the opportunities to bring region-specific topics into the classroom. An example of this was tackled in *Next Generation Climate*: using the National Climate Assessment to give students in various regions of the United States the ability to see how climate change will affect their specific area of the country.

There were three reasons for choosing to write a curriculum about climate change. First, I am not a classroom teacher anymore so there would not be a benefit from classroom or school-based research for this capstone project. Even though work-based research was an option, I thought that the creation of educational material would help the education community most. Second, climate change is one of the biggest issues of this era. Issues related to climate change are happening everyday and too many people keep ignoring them. Extreme storms, prolonged drought, and sea level rise can all be attributed to climate change. A curriculum seemed to be the best way to contribute to the education world without being in front of a classroom. We need more educational resources for educators and for the general public to use to ensure they understand the science of climate change. Planning and creating resources for teachers to use in their classroom or educational setting was my final reason for writing this curriculum. My behind the scenes work in education has been so enjoyable, curriculum writing just made sense as the next step.

Writing this curriculum was a journey I never thought I would be on. The behind the scenes side of education is exciting. As a researcher, I became overwhelmed at times combing through the information that has been written about the NGSS. However, I knew there was a great need for NGSS and climate change resources. Educators need resources that are easy to understand and implement.

I have been fortunate enough to be able to publish this curriculum with Climate Generation: A Will Steger Legacy, a non-profit in Minneapolis, MN whose mission is to educate and empower people to engage in climate change solutions. Through this publication, *Next Generation Climate* is already being downloaded by educators and the public, free of charge. Although it is not a part of this capstone project, I will be collecting data in the future from educators that have used this curriculum in their classrooms. This data will help me to edit and update *Next Generation Climate* in the future.

My goal of getting this curriculum into the hands of educators across the country is already happening. In addition to offering the curriculum free of charge online, I have already presented the finished product to educators and students, and at several local conferences. The activities I have presented to educators and students have been very well received. Educators enjoy the interdisciplinary nature of *Next Generation Climate* and students like the hands-on activities.

In the future, I would love to be able to update *Next Generation Climate* with current data, new graphs, and recommendations received from educators that have implemented the curriculum with their students. Science curriculum can very quickly become outdated and I do not want that to happen with *Next Generation Climate*.

It would also be great to write another curriculum in the future. I have learned a great deal about the process and the amount of work that goes into curriculum writing. It would be great to apply that knowledge to another curriculum. Continuing in the realm of climate change would be important, but choosing a different lens to look through would be fun. One of my passions in life right now is the intersection of climate change and food. How is climate change going to affect what food we are able to grow and how is our diet affecting the environment around us? This would be a great curriculum to write that could again be science-based and interdisciplinary. This new curriculum would be able to be implemented into science and social studies classrooms, just like *Next Generation Climate*. It could also be used in Family and Consumer Science classes and even used with the public in a public outreach project.

One interesting thing I learned during this project was understanding the need for new and exciting experiential education opportunities for students. While writing the section on the greenhouse effect, I knew that the concept was tricky for educators to portray and for students to understand. I looked far and wide for ideas about engaging students about the greenhouse effect and was very pleased with the final outcome: an interactive game that illustrated the greenhouse effect through a series of models. The first time the game was played with students, it was very well received.

The process of writing *Next Generation Climate* was positive, but there were also limitations within this capstone. While writing the Methods chapter of this capstone, I struggled to recall the specific steps I followed. During the research and writing process, I did not take very comprehensive notes and it was difficult to name each of the steps involved in writing. Going back and thinking about the process of designing *Next Generation Climate* was difficult. This resulted in a narrowed scope for the Methods chapter. There was more to the process than what is written in chapter three. Part of this was unintentional, but it also makes sense. Curriculum writing is an art, a dance. You can have a basic plan and path for how you would like to write the content, but as the writing progresses, it starts to shape itself. This may frustrate some readers, but it should be understood that even with a simple template and plan, a robust and useful curriculum can still be written.

I am very happy with the final product of this capstone project, the *Next Generation Climate* curriculum. The knowledge that I have gained about writing curriculum, researching for a large capstone project, and creating a product that helps students learn about climate change is priceless.

Climate change is the biggest issue the world is now facing. The world needs to come together to make big changes in how we live our lives. Understanding the science of climate change in order to make informed decisions about climate change and the repercussions we are facing is so important. The understanding begins with a quality education and becoming a climate literate person. *Next Generation Climate* can now be a resource to help create a climate literate society.

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Appendix A

Next Generation Climate Curriculum

Next Generation Climate

Grades 6-8

Next Generation Climate Academic Content Standards

Next Generation Science Standards (NGSS)

In 2013, the NGSS were released as the most current, research- based way of educating students in STEM and preparing them for STEM careers. The NGSS establishes high standards for delivering effective STEM education. They challenge us to provide the instructional support in our curriculum resources and to make NGSS accessible to educators in the classroom. Hands on learning, effective communication, making connections across all domains of science and other disciplines, an emphasis on including "all voices," and the importance of developing a learning progression are not only integral to the NGSS, but have always guided Climate Generation's development of educational resources.

NGSS performance expectations represent the final assessment of learning and therefore cannot fully develop a student's full mastery. Additionally, true NGSS instruction and learning is three dimensional- including not only core ideas (CI), but cross cutting concepts (CCC) and scientific and engineering practices (SEP) as well. Lesson plans that best support NGSS performance expectations, CI, CC and SEP are listed below.

Middle School Next Generation Science Standards	*Lesson 1*	*Lesson 2*	*Lesson 3*	*Lesson 4*	*Lesson 5*	*Lesson 6*
Human Impacts						
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.				•		•
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.		•			•	
Weather and Climate						
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century	•	•	•	•	•	
Engineering Design						
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.						•
Physical Science Disciplinary Core Ideas						
PS4B - Electromagnetic Radiation		•				•
Earth & Space Science Disciplinary Core Ideas						
ESS2D - Weather & Climate	•					
ESS3C - Human Impacts on Earth Systems		•	•	•	•	•
ESS3D - Global Climate Change	•	•	•	•	•	•
Engineering, Technology & Applications of Science Disciplinary Core Ideas						
ETS1B - Developing Possible Solutions				•	•	•
ETS1C - Optimizing the Design Solution						•

NGSS (cont.)

Middle School Next Generation Science Standards	*Lesson 1*	*Lesson 2*	*Lesson 3*	*Lesson 4*	*Lesson 5*	*Lesson 6*
Cross Cutting Concepts						
1. Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	•	•		•		
2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	•	•	•	•	•	•
3. Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.	•				•	
4. Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.		•				•
5. Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.		•				
7. Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	•	•	•	•		
Science and Engineering Practices						
1. Asking questions (for science) and defining problems (for engineering).	•	•	•	•	•	
2. Developing and using models	•	•			•	
3. Planning and carrying out investigations						•
4. Analyzing and interpreting data						•
6. Constructing explanations (for science) and designing solutions (for engineering)			•	•		•
7. Engaging in argument from evidence		•			•	
8. Obtaining, evaluating, and communicating information		•	•	•	•	•

Lesson Outcomes	Lesson Materials
Lesson 1: What evidence is there to show there is a rise in global temperature?	
• Students will be able to make conclusions about global temperature using various indicators as evidence. • Students will be able to ask questions that clarify evidence. • Students will be able to distinguish between weather and climate.	Global Land and Ocean Temperature Anomalies graph Lesson 1 Worksheet: Temperature Indicators Temperature Indicators Figure Set Temperature Indicators Figure Set Descriptions
Lesson 2: What factors have caused the rise in global temperature over the last century?	
• Students will be able to construct an argument, compare and critique multiple arguments, and analyze or interpret the facts presented. • Students will be able to investigate how temperature increase impacts and changes the atmospheric conditions. • Students will be able to demonstrate the greenhouse effect by showing how carbon dioxide and other greenhouse gases in the atmosphere trap heat and insulate the Earth. • Students will be able to determine how human population increase and per-capita consumption are contributing to the rise in global temperature and the concentration of greenhouse gases in the atmosphere. • Students will be able to distinguish between the greenhouse effect and climate change.	Human Impact Cards Lesson 2 Worksheet 1: Claim, Evidence, Reasoning Evidence Figure Set Evidence Figure Set Descriptions Lesson 2 Worksheet 2: Discussion Diamond Separating Human and Natural Influences on Climate figure
Lesson 3: What are the repercussions of the rise in global temperature?	
• Students will be able to explain several repercussions of climate change where they live using the National Climate Assessment, among other resources. • Students will be able to explain what makes a good scientific resource.	Ten Indicators of a Warming World graphic Lesson 3 Worksheet 1: Climate Change Repercussions Research Project Lesson 3 Worksheet 2: National Climate Assessment Scavenger Hunt National Climate Assessment Scavenger Hunt Answer Key
Lesson 4: What would you need to monitor the repercussions of the rise in global temperature?	
• Students will be able to describe how scientists are monitoring the repercussions of climate change. • Students will be able to explain what citizen science is and be able to participate in a citizen science project.	Lesson 4 Worksheet: Scientists in Action Scientist Stories Citizen Science slideshow
Lesson 5: In what ways can the repercussions of climate change be minimized?	
• Students will be able to explain the difference between adaptation and mitigation, and provide many examples of each. • Students will be able to debate about the positives and negatives of mitigation and adaptation solutions using the CER framework.	Impacts, Mitigation, and Adaptation Prompt Lines Mitigation and Adaptation Venn Diagram Lesson 5 Worksheet 1: Adaptation and Mitigation Scenarios Lesson 5 Worksheet 2: Claim, Evidence, Reasoning (Mitigation and Adaptation)
Lesson 6: How can you design a method for monitoring and minimizing climate change?	
• Students will be able to use the engineering design process to create a way to monitor and minimize human impact on the environment.	

Age Level	Grades 6-8
Time Needed	Two 50 minutes class periods
Materials	Global Land and Ocean Temperature Anomalies graph Worksheet: Temperature Indicators Temperature Indicators figure set (1 set of 12 for class) Temperature Indicators figure set Descriptions (if using) Science journal for each student
Vocabulary	**indicator:** a sign that shows the condition or existence of something (factors). **weather:** the atmospheric conditions of a specific place at a specific point in time. **climate:** the weather conditions over a given time interval (months, years). **trend:** A general tendency or course of events: a warming trend. **climate change:** a change in the typical or average weather of a region or city. This could be a change in a region's average annual rainfall, or it could be a change in a city's average temperature for a given month or season. **anomaly:** a deviation from the common rule (exception).
Student Learning Outcomes	• Students will be able to make conclusions about global temperature using various indicators as evidence. • Students will be able to ask questions that clarify evidence. • Students will be able to distinguish between weather and climate.
Performace Expectation(s) addressed	**MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Print each page of the Global Land and Ocean Temperature Anomalies graph. • Print a classroom set of the Temperature Indicators figure set and Temperature Indicators Figure Set Descriptions (if using) • Make copies of Temperature Indicators worksheet for each student. • Students will need a science journal for these lessons. Make journals with students during class or use composition notebooks. Journals will make great summative assessments at the end of the six lessons or to use as formative assessments throughout the unit. • Before beginning this lesson, have students go home and interview an older relative about weather and climate. Students should ask their relative about what they remember about the weather when they were younger. They will share their stories with the class. • Consult the Questioning Guide in the front of this curriculum for detailed structure on questioning and how to elicit good questioning.

Lesson 1: What evidence is there to show there is a rise in global temperature?

Indicators around the world

Background Information

In this lesson students are introduced to evidence that shows there has been a rise in global temperature over the past century and be asked to make their own conclusions using the evidence. This lesson will introduce many indicators that illustrate the global temperature rise, and also explain the difference between weather and climate.

This lesson will also introduce students to other indicators that indicate increasing temperatures around the world. While surface air temperature is the most widely cited measure of climate change, other indicators of temperature change are often more directly relevant to both human society and the natural environment. Examples include information that show changes in the arrival date of migratory bird species in the spring, the amount of area burned by wildfire each year, or reduced lake levels due to increased evaporation. The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events—like heavy rain storms and record high temperatures—are already taking place.

> *The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events—like heavy rainstorms and record high temperatures—are already taking place.*
>
> *- Environmental Protection Agency*

Being able to differentiate between weather and climate is crucial when learning about climate change. Weather is the atmospheric conditions of a specific place at a specific point in time. For example, the weather in Seattle on April 25th, 2014 was 63 degrees with light rain. Weather is what is going on outside the window right now.

Climate is the weather conditions over a given time interval. Climate descriptions include the physical and biological features of the land, and their interactions with the atmosphere. When using the Seattle example, one would say the climate in the winter is wet and cool. Climate is what you expect, weather is what you get.

Understanding how temperatures are monitored is also helpful when discussing climate change, because you need to know that the data can be trusted. The simplest way temperatures are recorded are from land monitor stations. There are also buoys and ships in the ocean that monitor temperature. Most of these stations are from the Global Historical Climatology Network (a database of climate summaries from land surface stations across the globe). It is also important to note that few stations exist in the arctic, where the warming is more extreme. Thus, the raw temperature data does not reflect the true extent of the warming. There are many types of observations that can be used to detect changes in climate and determine what is causing these changes. Thermometer and other instrument-based surface weather records date back hundreds of years in some locations. These surface temperatures are measured at fixed locations over land and by ship or buoy over the ocean. Over the years, we have been able to record upper air temperatures and map precipitation with weather balloons and satellites.

In addition to raw temperature data, there are many methods that exist to estimate the temperature centuries and millennia ago. Raw temperature data only goes back to around 1880. However, scientists can get clues from ice core data, geological formations, tree rings, and others to get an idea of what the temperature was at a given time. These climate "proxies" – biological or physical records that correlate with aspects of climate – provide further evidence of past climate that can stretch back hundreds of thousands of years.

Journal Assignment

At the end of this lesson, students will write the definition and an analogy to explain the difference between weather and climate in their journals. Students will also write a description about how climate change is already affecting the area where they live. Finally, students should paste the Temperature Indicators worksheet in their notebooks to reference later.

Activity Description

Introduction: What's happening to global temperatures?

1. In small groups, students will receive a piece of the Global Land and Ocean Temperature Anomalies graph. Define anomalies for students and explain that this graph shows the temperature change from average. Have a discussion about how to ask good clarifying questions with your students. A clarifying question does not provide new information, but expands on understanding the information that is already presented. In their journals, ask students to list questions they should ask when clarifying evidence. Clarifying questions could include:

    a. Who collected this data?
    b. When was it collected?
    c. Does it represent what it's supposed to?
    d. Who funded the research?

2. Allow students a few minutes to look at the graph. Ask students to come up with 3 questions they can ask to help clarify the evidence before them and 3 things they notice about the evidence. Ask students to write their responses on sticky notes.

3. Groups will share their responses with the class. Help students understand the importance of asking clarifying questions to ensure they are using sound evidence. Share the paragraph about the graph with the students and bring up the source website if needed. Other discussion questions to ask your students:

    a. What do you notice about this ~25 year segment?
    b. What conclusion about temperature can you draw from your 25-year segment?
    c. What do you think is causing the changes in your segment?
    d. Based on your segment, what do you think the next 20 years will look like?
    e. Did your questions lead you to a deeper understanding of the graph?
    f. What do you still have questions about?

4. Ask students to bring their graph segment to the front of the room and put them together. This is the Global Land and Ocean Temperature Anomalies graph. It shows the average temperature for each year starting in 1880 until 2015. Once the graph is together, students will be able to see that the temperature is in fact increasing. Remind students that this graph shows average temperature (some places may get colder one year, but overall the temperatures are increasing).

    a. Lead a discussion about looking at this graph as a whole, instead of in pieces. Why is it important to look at change over time (years, decades, centuries)?

Activity 1: Difference between weather and climate

1. Before beginning this activity ask students to interview an older relative about weather and climate. Students should ask their relative about what they remember about the weather when they were younger. Students will share their stories with the class.

    a. Are there any patterns they notice about the stories they are hearing from their classmates?
    b.Do these stories constitute reliable evidence? Why or why not?
    c. What would make them more reliable?

2. In their journals, ask students to describe the weather right now, being as detailed as possible. Then ask students to describe the climate where they live in their journals. Have students share their thoughts with a partner. After talking with their partner, students may want to change their answer. Ask a few groups to share their answers with the class.

3. Show the following definition of weather and climate to your students. Students should include these definitions in their notebook:

> **Weather:** the atmospheric conditions of a specific place at a specific point in time, the minute-by-minute variable condition of the atmosphere on a local scale
> **Climate:** how the atmosphere "behaves" over relatively long periods of time (months, years), the description of an area's average weather conditions and the extent to which those conditions vary over long time intervals

The difference between weather and climate is a measure of time. Weather is what you wear each day. Climate is the clothes you have in your closet.

4. Show the following video to help illustrate the difference between weather and climate with your students.
Trend and Variation: http://www.climategen.org/ngconline.

5. Look back at the *Global Land and Ocean Temperature Anomalies* graph from the beginning of this activity. How would you describe the difference in global temperatures in 1909 and 1998? Can you describe the weather of those two years? Why or why not?

6. To finish this activity, ask students to choose their favorite way of describing the difference between weather and climate and draw or write that description in their journal.

Activity 2: What are the indicators of the rise in global temperature? How do you ask clarifying questions?

1. What are the indicators that show us the global temperature is rising? Measurements from scientists, citizens, and students like yourselves can show us that temperatures around the world are going up. In this activity, students look at how measurements are made and draw conclusions about the global temperature after looking at multiple lines of evidence.

2. Ask students "Besides looking at a thermometer, what are things you see that indicate changes in temperature?" (i.e. ice out early on lakes, less ice cover on lakes, sea level rise because of melting glaciers) Make a list of the board.

3. Split class into 6 or 12 small groups. Give each group 1-2 figures from the *Temperature Indicators Figures Set* and give each student a worksheet of the same title.

4. Each group will study their figure(s), discover what indicators are shown, and answer questions on a provided worksheet to help clarify and ensure the evidence is reliable. The worksheet is provided on page 12.

5. After students have studied the figures they will present what they found to the class. Hang figures in classroom for students to reference throughout the unit.

Note: Teachers may decide to share the explanatory information given in the *Temperature Indicators Figure Set Descriptions* with students after they have made their own interpretations.

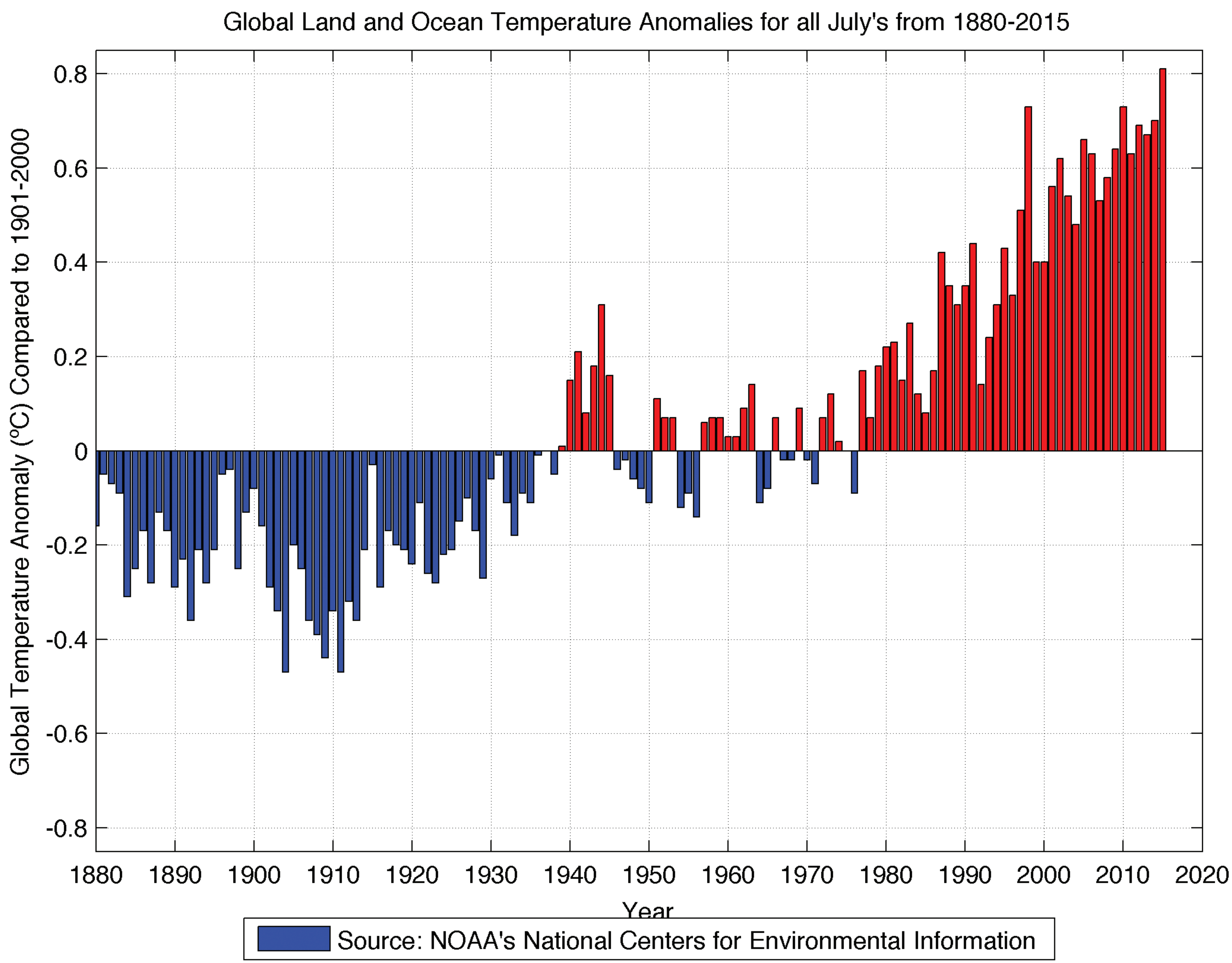
Conclusion:

1. Invite students to explore the figures they analyzed, as well as the ones their classmates looked at. Figures should be posted around the room and students can get up to look at them during this activity. Pose the question, what can we learn from multiple lines of evidence? When looking at the figures all together, what conclusions can be drawn?
2. These figures, when put together, provide the evidence for what is being called global climate change, the increase in the globe's average temperature and precipitation.
3. With a partner (or with their groups), ask students to choose two figures and write about how evidence in those figures is related to the area where they live, i.e. how is climate change impacting them? Are they seeing these indicators now, or will they in the future?

Take it Outside: In order to practice taking measurements and see how scientists monitor changes in the atmosphere, take your class outside. With thermometers, anemometers, rain gauges (that have been placed there a few days in advance), and other weather collection tools, students will practice taking measurements. Have students write their observations in their journals. Use this website to collect weather data to be used in research and educational purposes around the world: http://www.cocorahs.org/

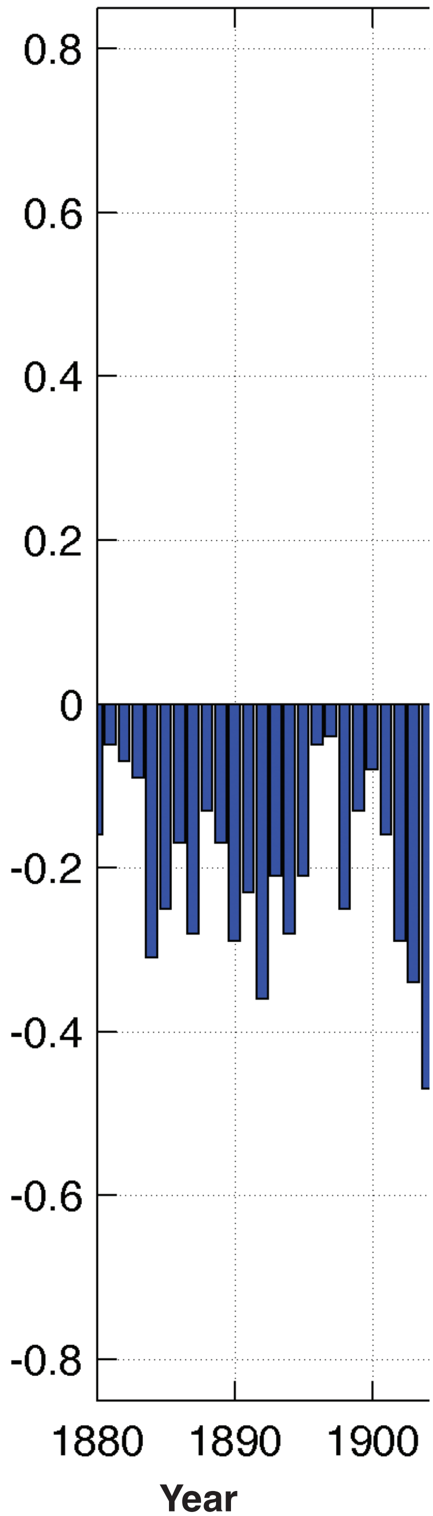
References

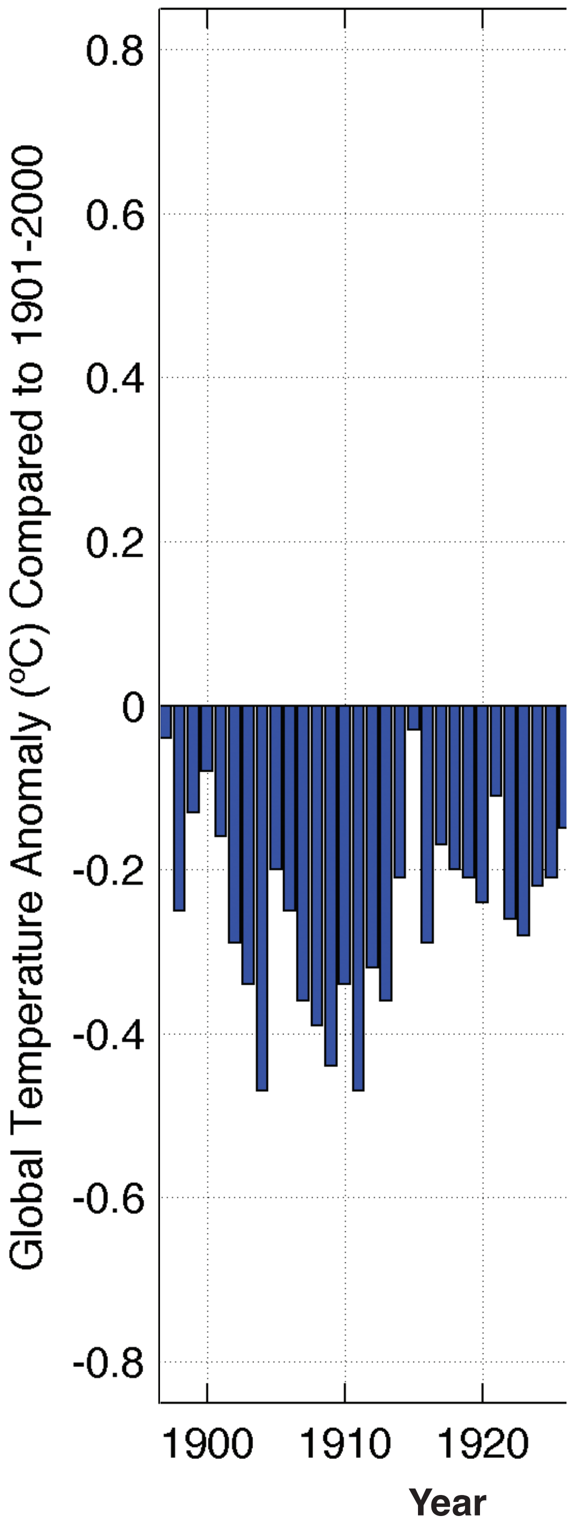
Background information gathered from the following websites:
http://nca2014.globalchange.gov/report/appendices/climate-science-supplement
http://www.ncdc.noaa.gov/



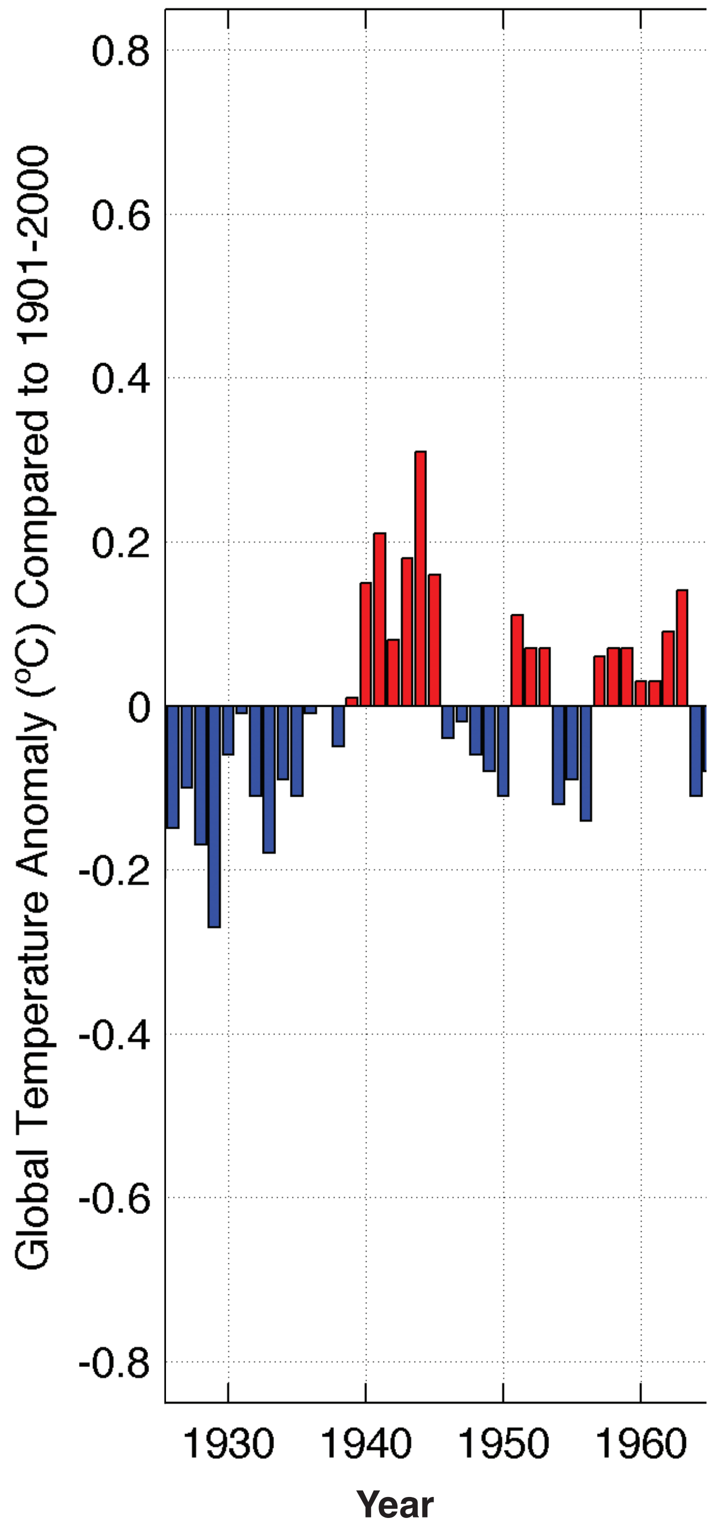
The graph shows average annual global temperatures since 1880 compared to long-term average (1901-2000). The zero line represents the long-term average temperature for the whole planet; blue and red bars show the difference above or below average for each year. The National Oceanic and Atmospheric Administration collected the temperature data from locations around the world.

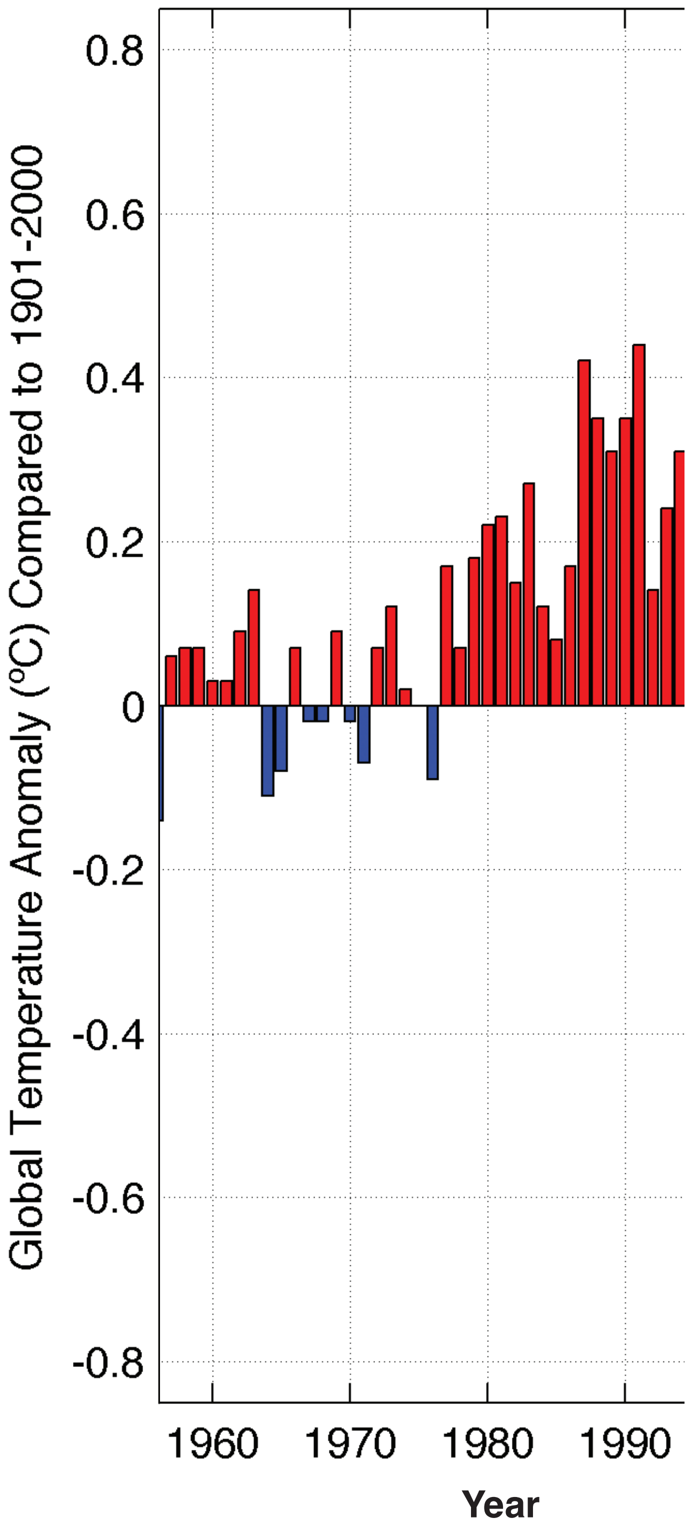
Data Center. (2015). Climate Change: Global Temperature. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

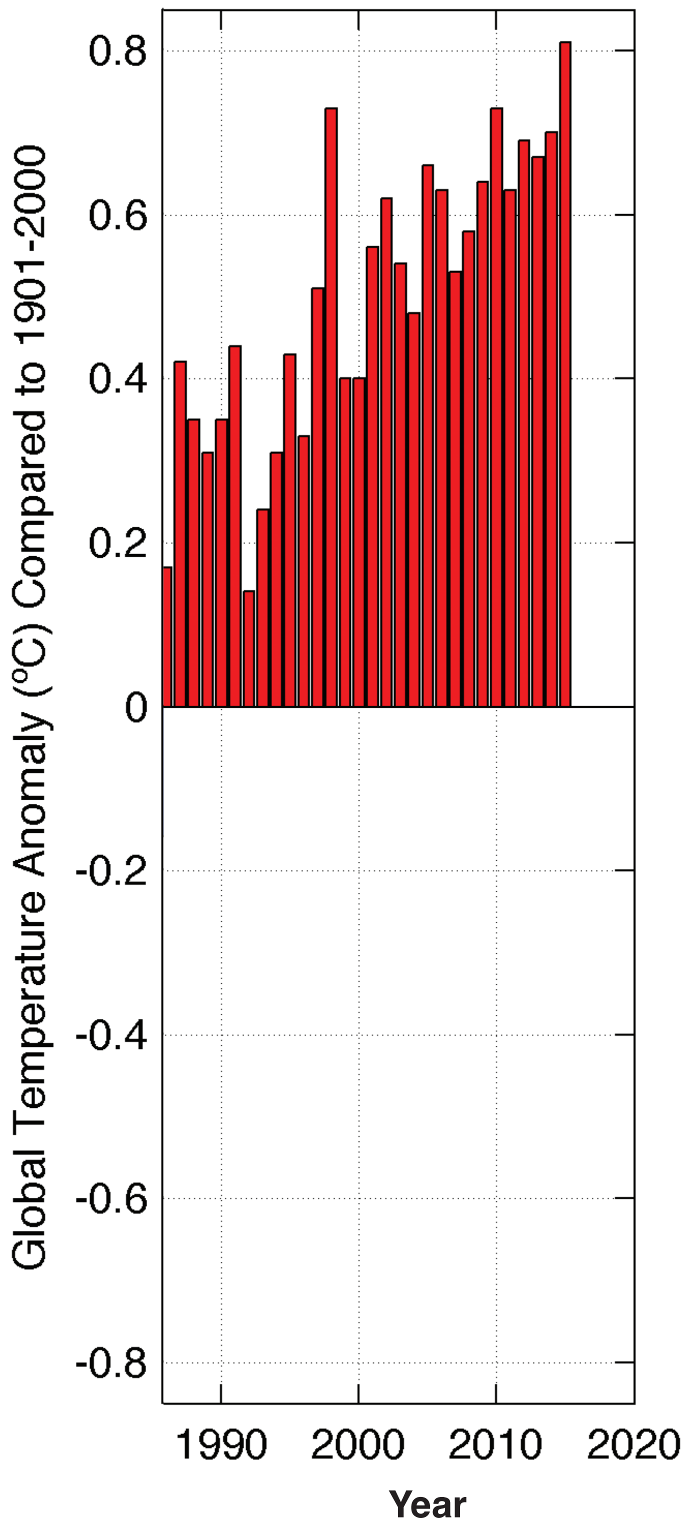

0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1880
1890
1900
Year



Global Temperature Anomaly (°C) Compared to 1901-2000
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1900
1910
1920
Year


Global Temperature Anomaly (°C) Compared to 1901-2000
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1930
1940
1950
1960
Year


0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Global Temperature Anomaly (°C) Compared to 1901-2000
1960
1970
1980
1990
Year


0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Global Temperature Anomaly (°C) Compared to 1901-2000
1990
2000
2010
2020
Year

Student Worksheet: Temperature Indicators

Group Members ______________________________

Which figure are you looking at ______________________________

1. What is the first thing that you notice about this figure?

2. What is one thing about this figure that you find interesting?

3. What questions do you have about this figure? Write them down. Think of at least 3.

4. Does this figure represent climate data or weather data? Explain.

5. Write one sentence about what this figure is saying (include specific data from figure).

6. What does the information tell you about global temperatures?

7. How did scientists collect this data? (scientific instruments, scientist's eyes, citizen's eyes, traveling, other)

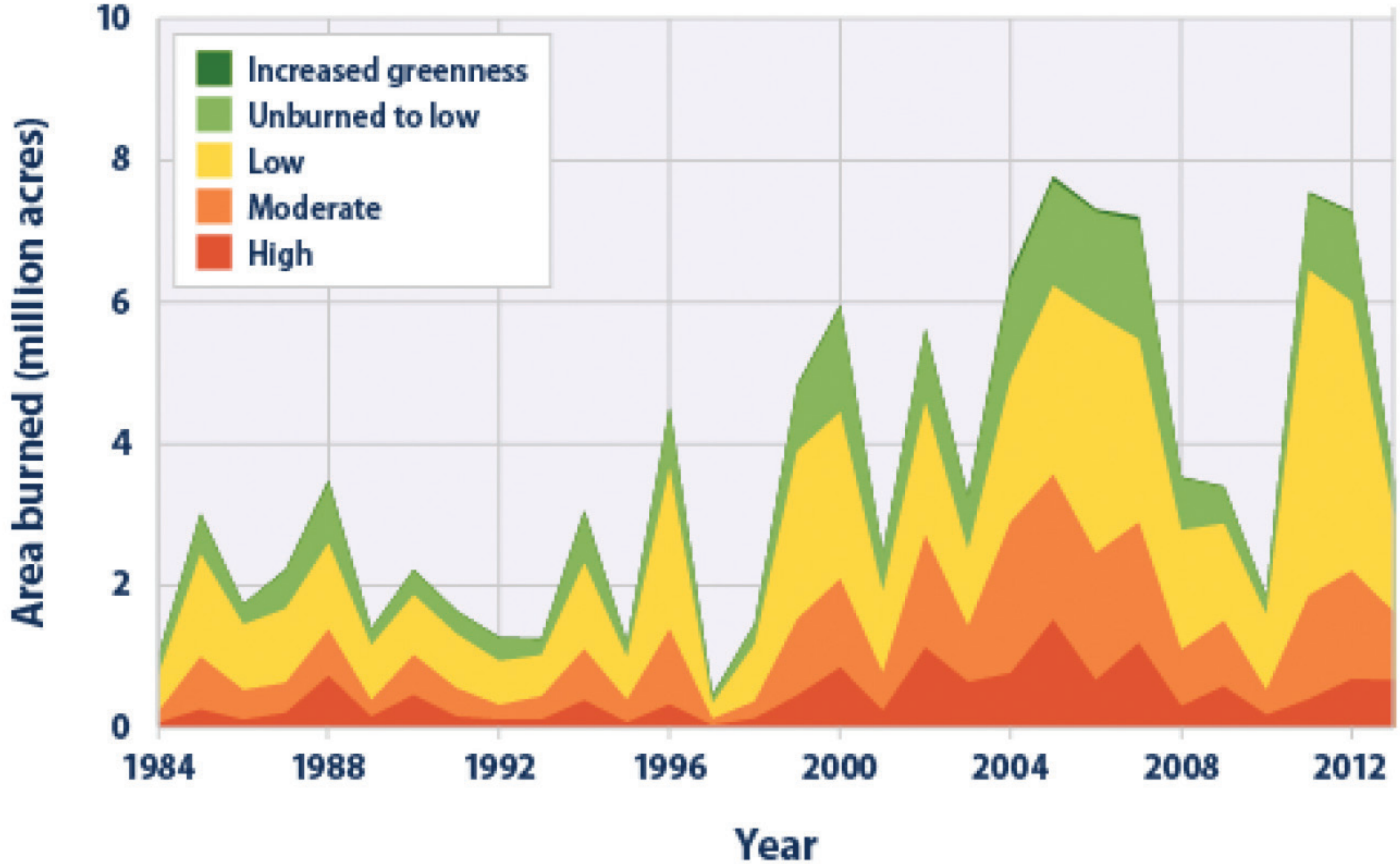
8. What organization or person collected the information?

9. When was the data collected?

10. Write down a question that you would ask the creator of the figure or the researcher behind the information?

11. Is this reliable (able to be trusted) data? Why or why not?

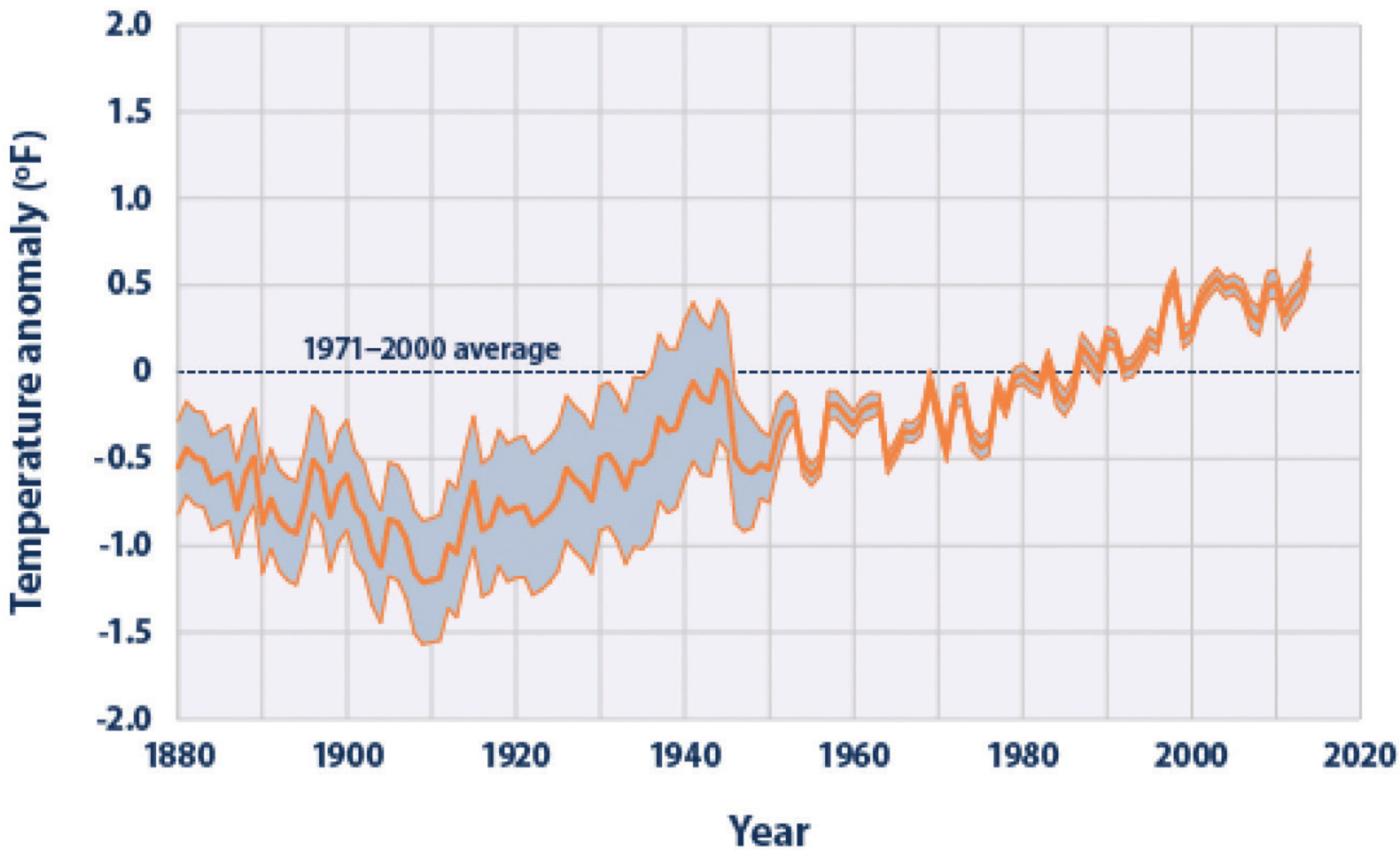
Figure 1 — Damage caused by Wildfires in the United States



Data source: MTBS (Monitoring Trends in Burn Severity). 2015. MTBS dat summaries. Www.mtbs.gov/data/search.html. For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/ecosystems/wildfires.html

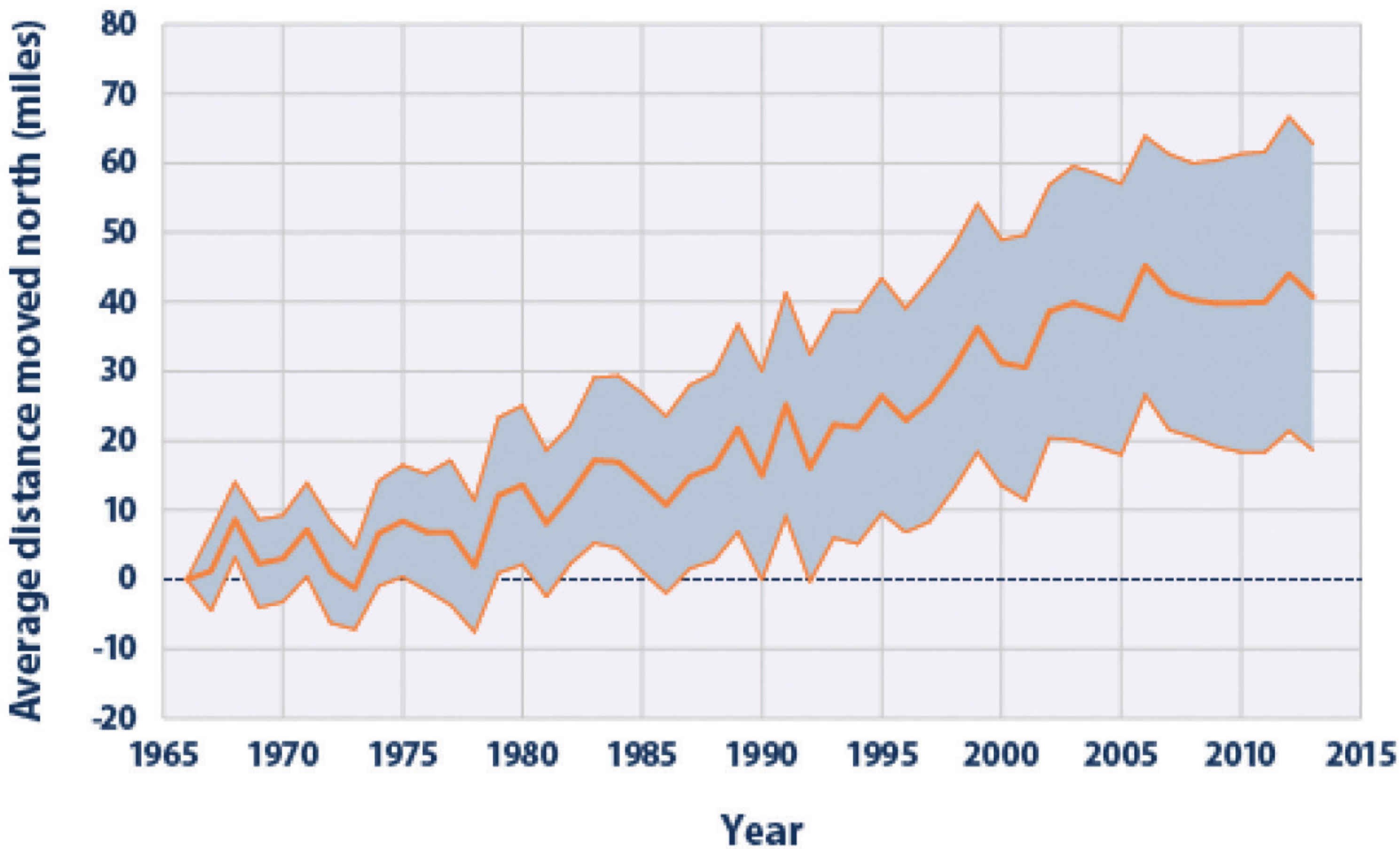
Figure 2 — Average Global Sea Surface Temperature



Data source: NOAA (National Oceanic and Atmospheric Administration). 2015. Extended reconstructed sea surface temperature (ERSST.v3b). National Centers for Environmental Information. Accessed April 2015. www.ncdc.noaa.gov/ersst. For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/oceans/sea-surface-temp.html

Figure 3 — Change in Latitude of Bird Center of Abundance



Data source: National Audubon Society.2014 update to data originally published in: National Audubon Society. 2009. Northward shifts in the abundance of North America birds in early winter: A response to warmer winter temperatures? Www.audubon.org/bird/bacc/techreport.html. For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/ecosystems/bird-ranges.html.

Figure 4 — Ice Cover in the Great Lakes

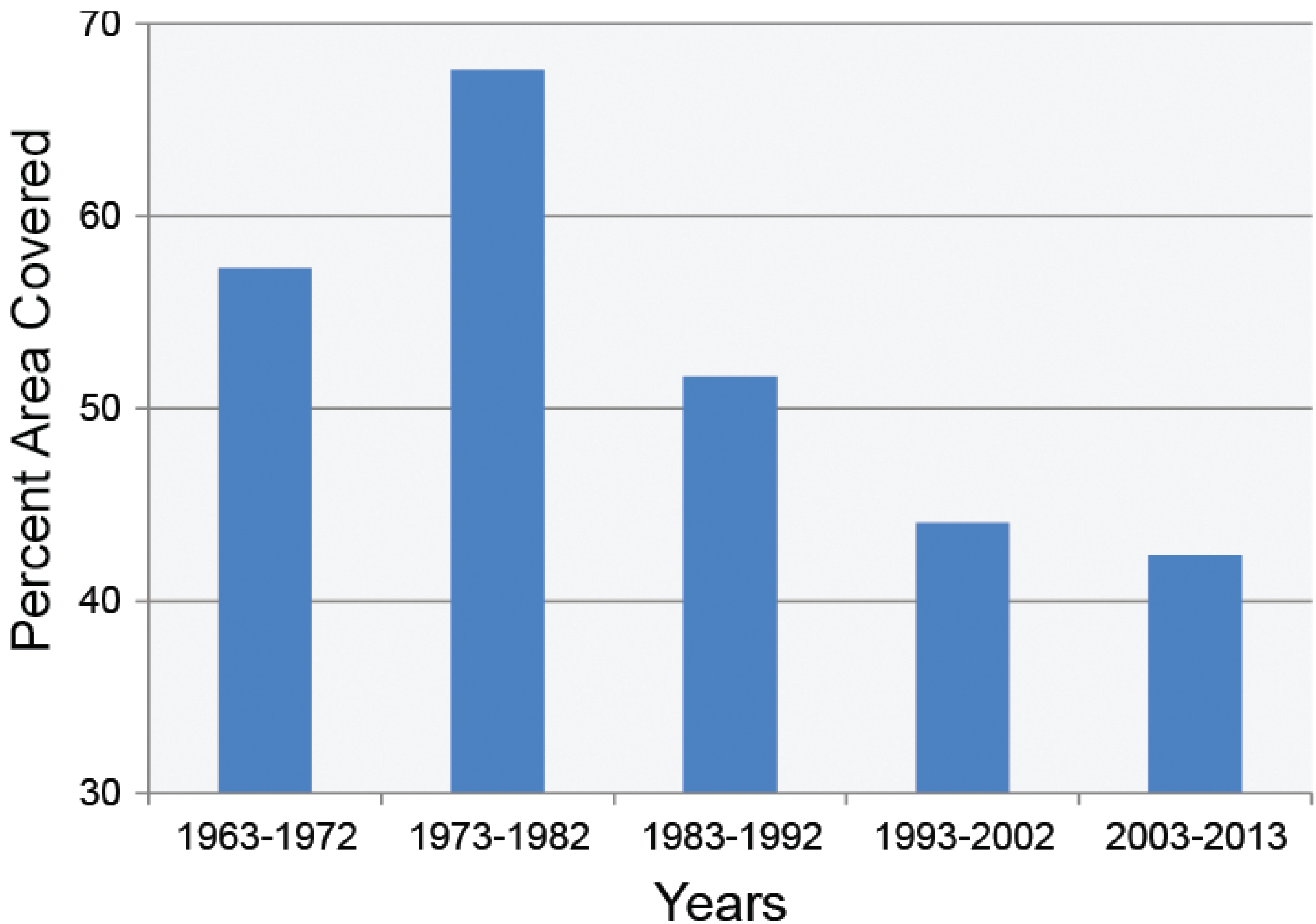


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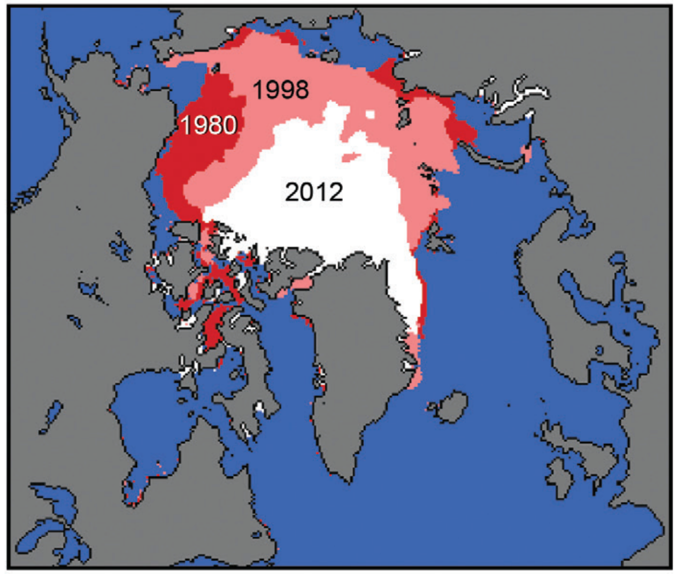
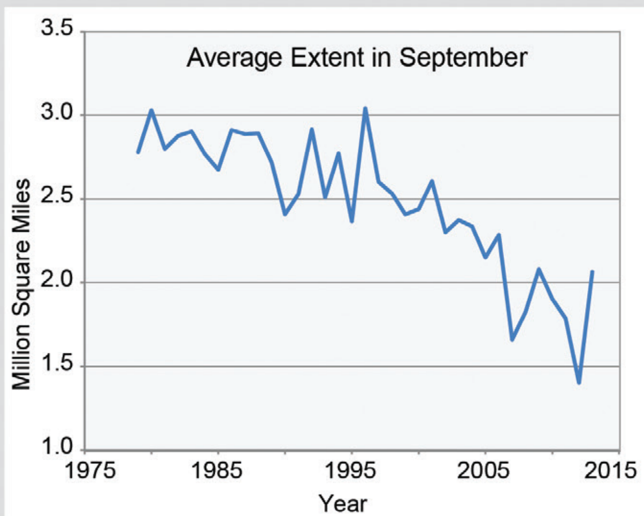
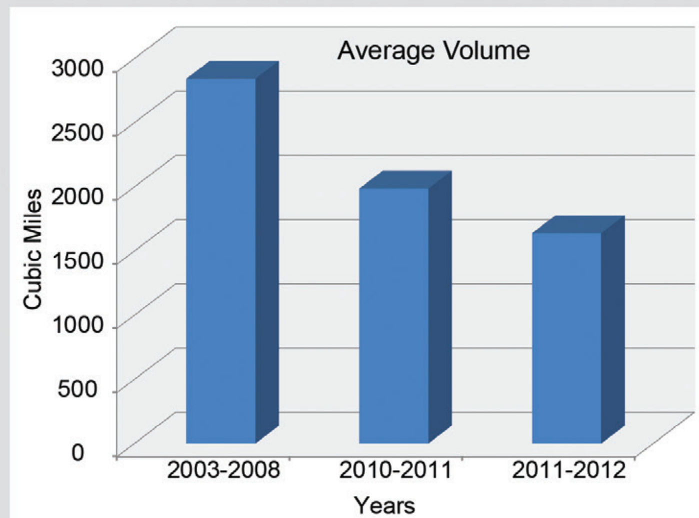
Figure 5 — Arctic Sea Ice Loss

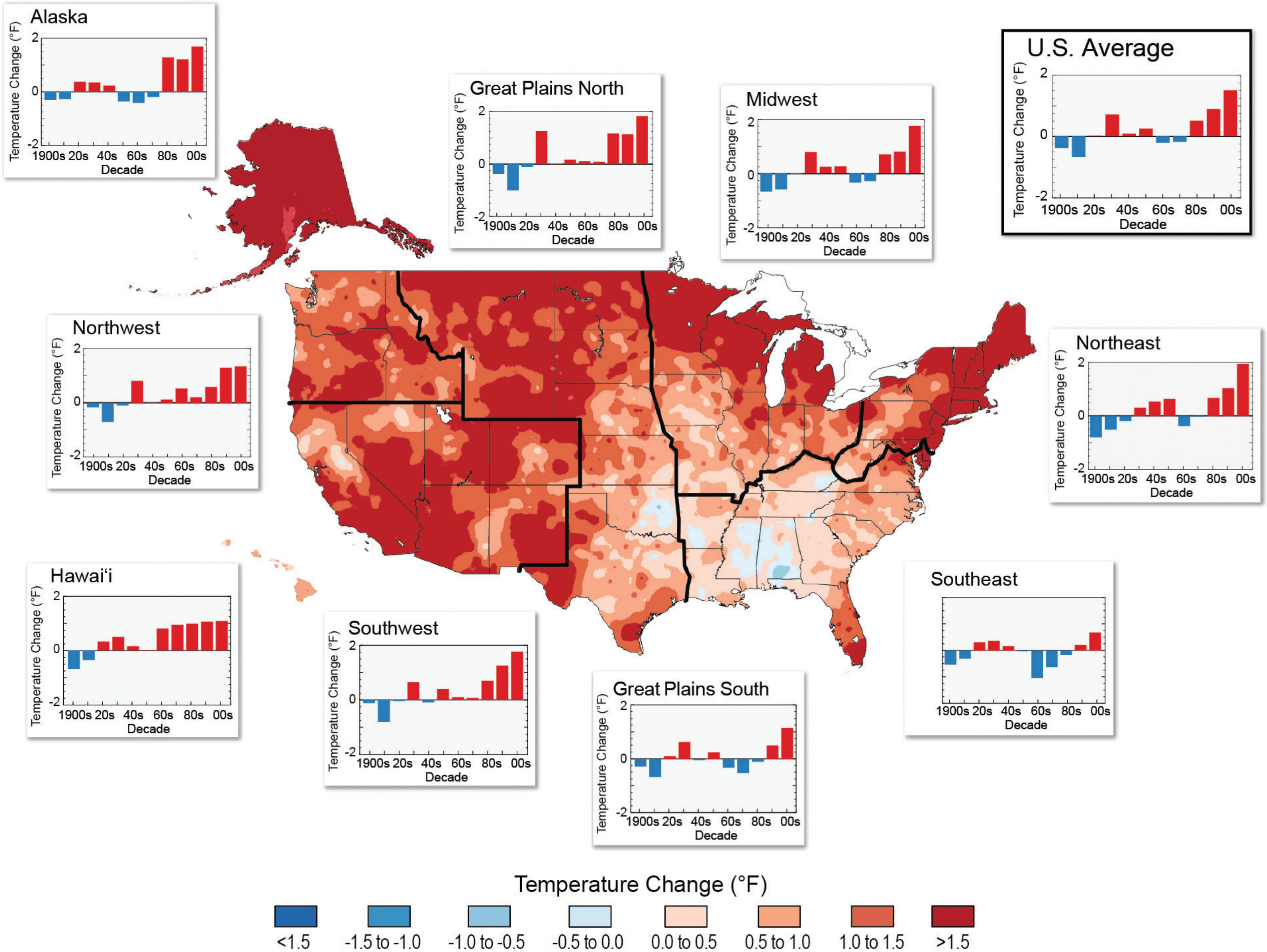






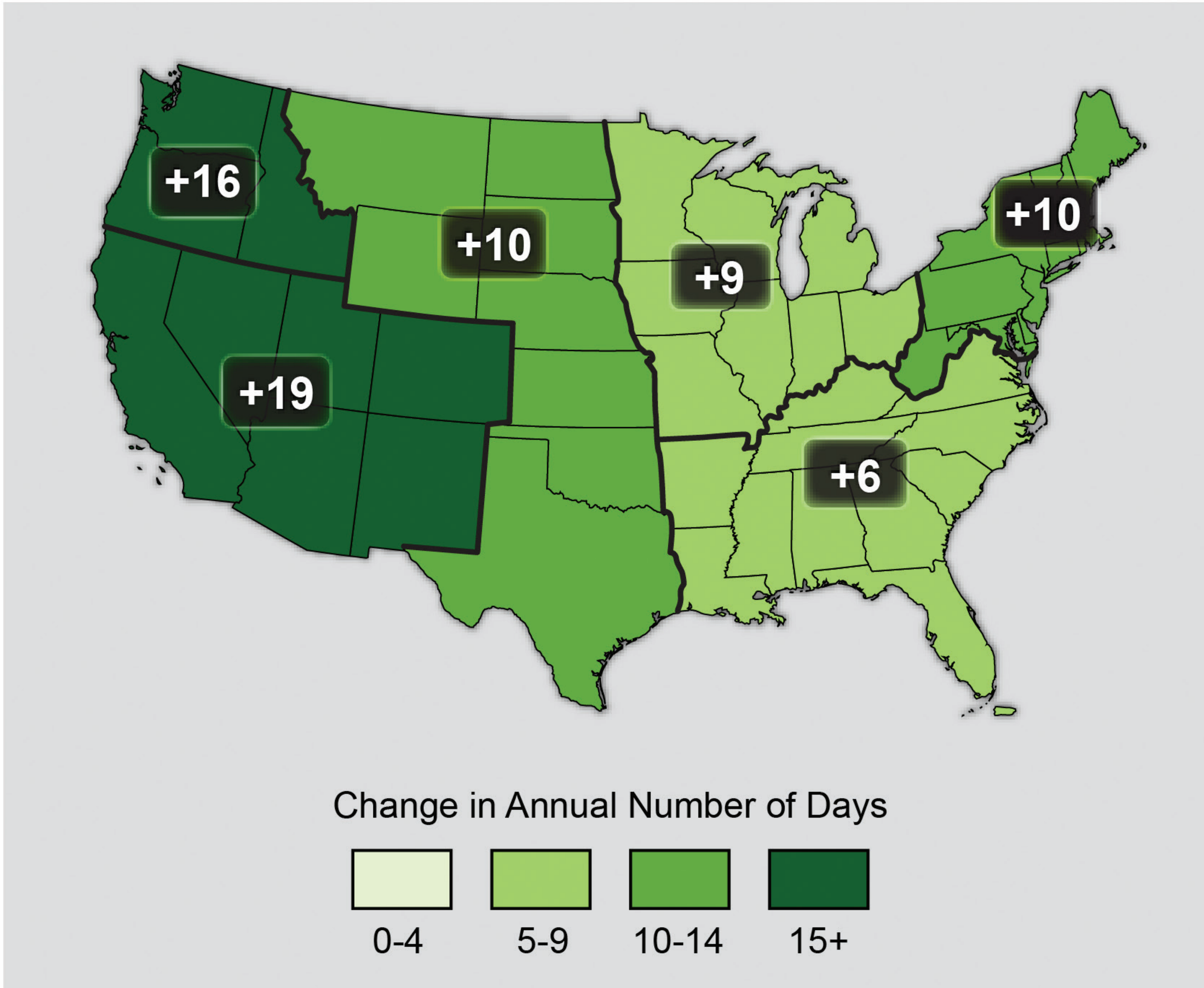
National Climate Assessment and Development Advisory Committee. (2014). Melting Ice. Retrieved from http://nca2014.globalchange.gov/report/our-changing-climate/melting-ice

Figure 6 — Observed U.S. Temperature Change



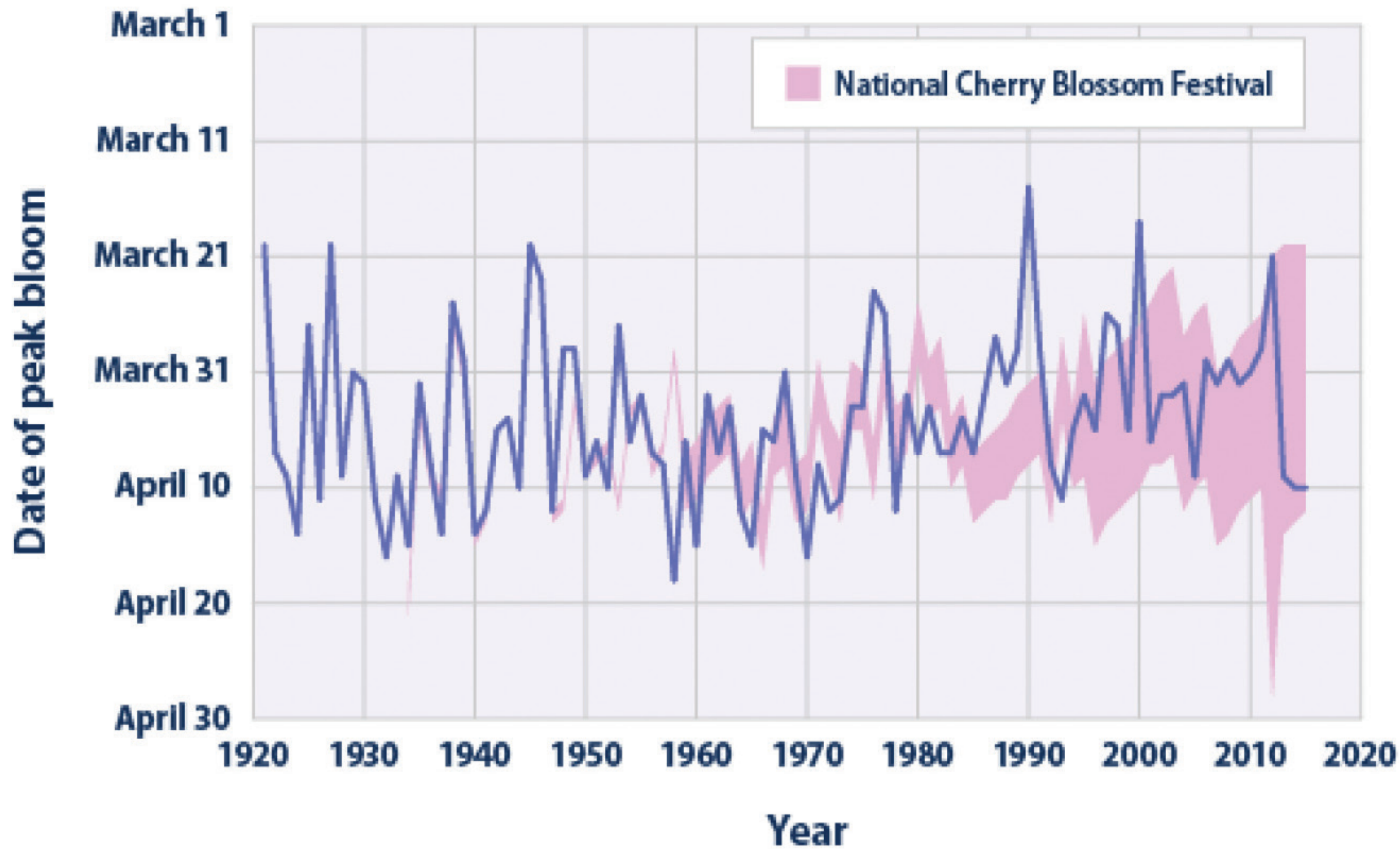
National Climate Assessment and Development Advisory Committee. (2014). Our Changing Climate. Retrieved from http://nca2014.globalchange.gov/highlights/report-findings/our-changing-climate#graphic-20970

Figure 7 — Observed Increase in Frost-Free Season Length



National Climate Assessment and Development Advisory Committee. (2014). Frost-Free Season. Retrieved from http://nca2014.globalchange.gov/report/our-changing-climate/frost-free-season

Figure 8 — Peak Bloom Date for Cherry Trees Around Washington D.C.'s Tidal Basin



U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/ecosystems/cherry-blossoms.html

Figure 9 — Ten Indicators of a Warming World

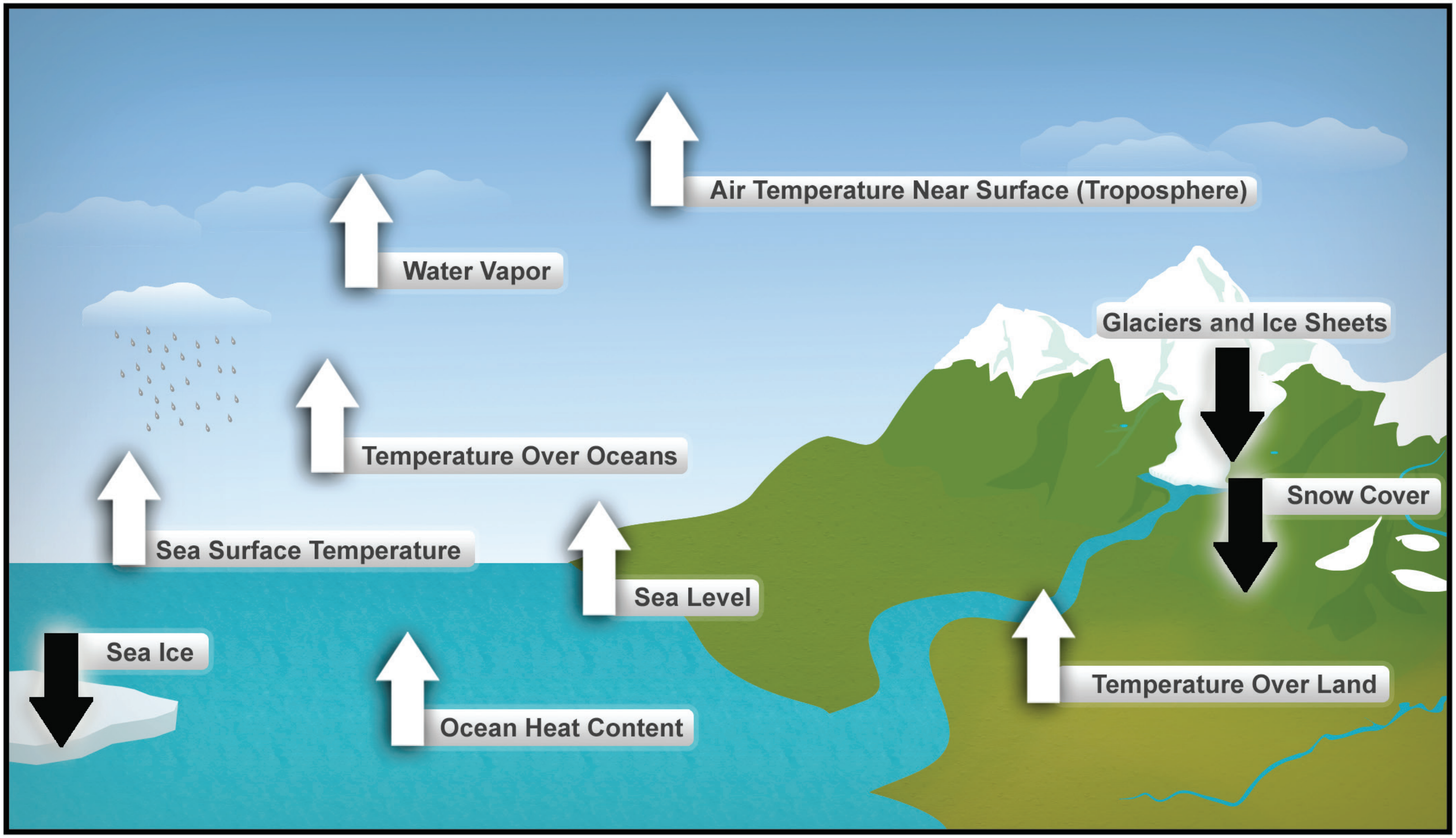
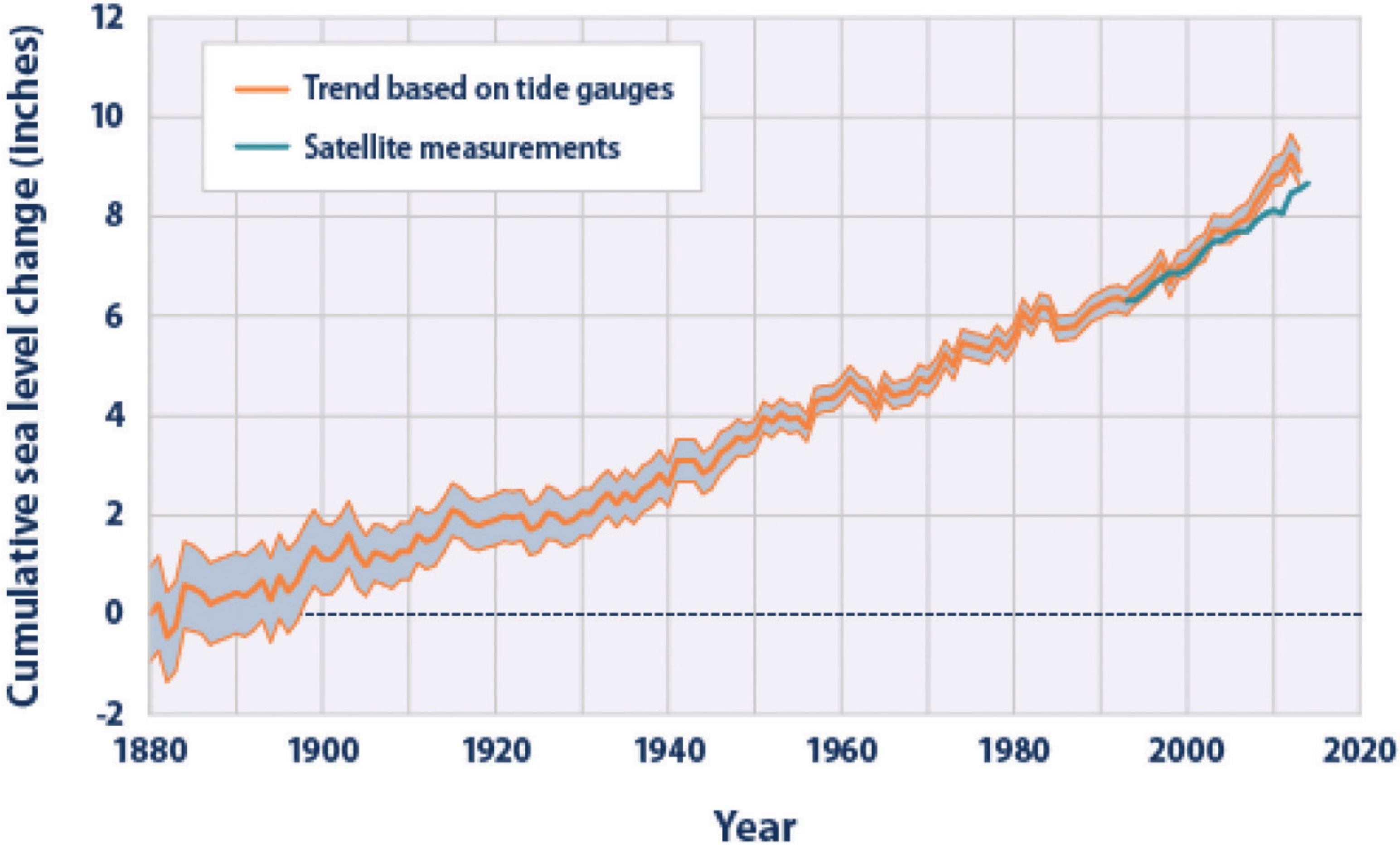


Figure 10 — Global Average Sea Level Change



Data Sources:
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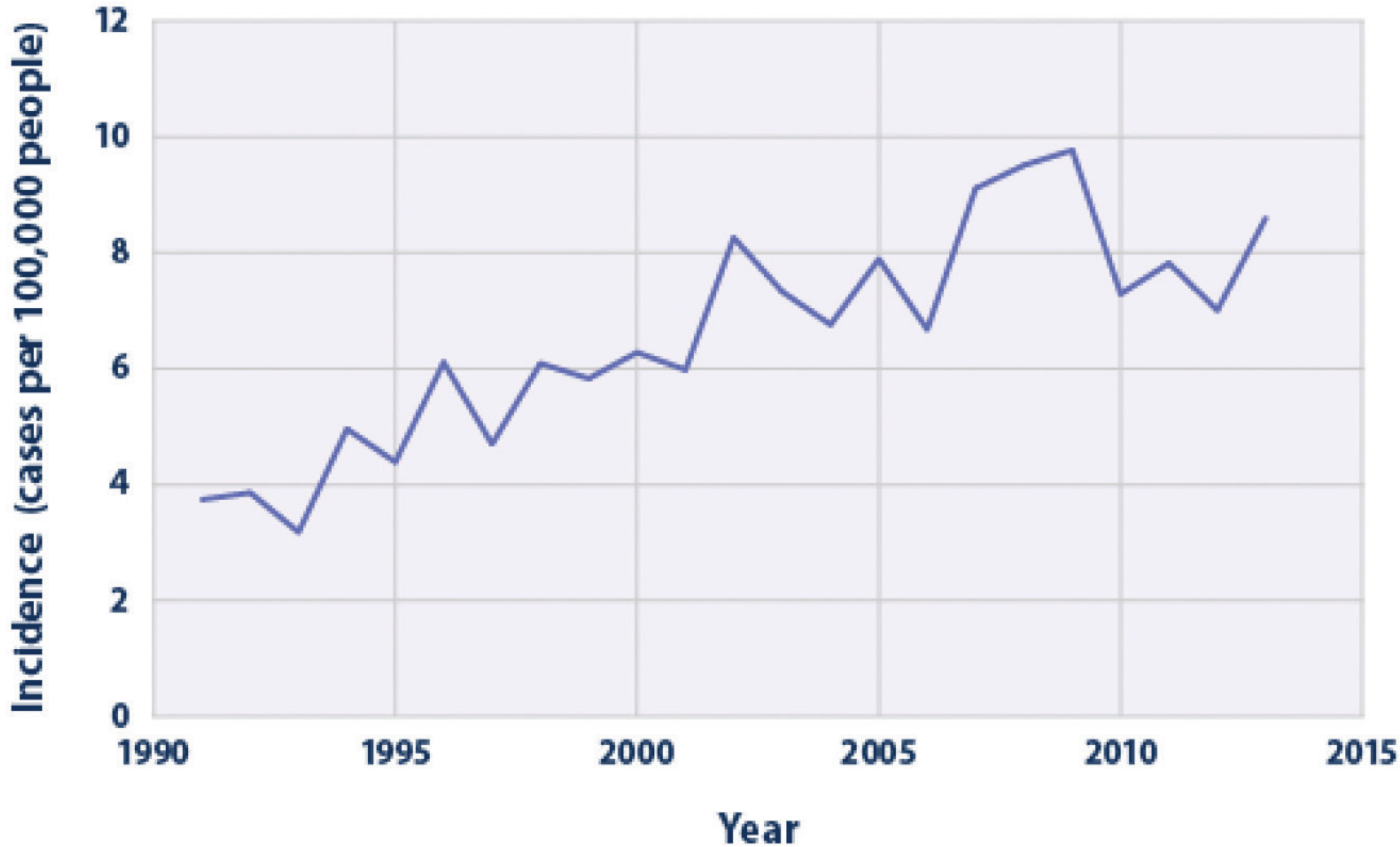
- NOAA (National Oceanic and Atmospheric Administration). 2015. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2015. http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_timeseries_global.php

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www. epa.gov/climatechange/indicators.

U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/health-society/lyme.html

Figure 11 — Reported Cases of Lyme Disease in the United States



Data source: CDC (Centers for Disease Control and Prevention). 2015. Lyme disease data and statistics. www.cdc.gov/lyme/stats/index.html. Accessed March 2015. For more information, visit U.s. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

U.S. Environmental Protection Agency. (2015). Climate Change Indicators in the United States. Retrieved from http://www.epa.gov/climatechange/science/indicators/health-society/lyme.html

Figure 12 — Change in Muir Glacier from 1941 & 2004

1941 photo taken by Ulysses William O. Field; 2004 photo taken by Bruce F. Molnia. Courtesy of the Glacier Photograph Collection, National Snow and Ice Data Center/World Data Center for Glaciology. NASA Jet Propulsion Laboratory. (n.d.). Images of Change. Retrieved from http://climate.nasa.gov/state_of_flux#Icemelt.jpg

Temperature Indicators Figure Set Descriptions

Figure 1 — Damage caused by Wildfires in the United States: This figure shows the damage from wildfires by acreage across the United States. The severity of each fire is measured by comparing the "greenness" of satellite images taken before and after a fire. Burn severity provides an indication of the damage done and can help scientists predict how long it will take for the location to recover. Climate change can impact wildfires because with warmer temperatures, forests become more vulnerable to fires. This is due to drought and large temperature changes.

Figure 2 — Average Global Sea Surface Temperature: This figure shows how the average surface temperature of the world's oceans has changed since 1880. The shaded regions show the amount of uncertainty. Notice how those bands of shaded regions decrease dramatically around 1950, showing how the instruments used to measure sea surface temperature have dramatically improved. These measurements were made by buoys and ships in the ocean that monitor temperature. Sea surface temperature is an important indicator for the warming planet because ocean covers the majority of the earth. Slight changes in sea surface temperature can change ocean currents and impact many ocean species. Additionally, as the oceans warm, an increase in evaporation will lead to more water vapor, a very powerful greenhouse gas.

Figure 3 — Change in Latitude of Bird Center of Abundance: This figure shows the change in latitude of bird center abundance for 305 species of North American birds. The center of abundance is a point on the map the represents the middle of each species' distribution. If a species shifts northward with its range, then the center of abundance would shift north as well. Each winter is represented by the year in which it began. For example, winter 2013-2014 is shown as 2013. Many people and institutions (students and scientists) have kept detailed records of birds for over a century. This data relies on people all over the continent keeping track and observing certain species of birds, including their migration arrival and departure dates.

Figure 4 — Ice Cover in the Great Lakes: This bar graph shows decade averages of annual maximum Great Lakes ice coverage starting from the winter of 1962-1963, when reliable coverage of the entire Great Lakes began, to the winter of 2012-2013. Bar labels indicate the end year of the winter; for example, 1963-1972 indicates the winter of 1962-1963 through the winter of 1971-1972. The average maximum for 2003-2013 was less than 43% compared to the 1962-2013 average of 52%. Less ice, coupled with more frequent and intense storms, leaves shores vulnerable to erosion and flooding and could harm fish habitat.

Figure 5 — Arctic Sea Ice Loss: Arctic sea ice has declined dramatically since satellites began measuring it in 1979. The extent of sea ice in September 2012, shown in white in the top figure, was more than 40% below the average for 1979-2000. The graph on the bottom left shows annual (yearly) variations in September Arctic sea ice extent for 1979-2013. It is also notable that the ice has become much thinner in recent years, so its total volume (bottom right) has declined even more rapidly than the extent. As ice cover decreased in the Arctic, it reduces the amount of reflective ice surface, allowing the dark water to absorb more energy, thus perpetuating the warming even further. More open water and a warmer Arctic can lead to changes in the precipitation and the jet stream (a river of air in the atmosphere that steers our weather), often allowing cold air to drift farther south in the winter.

Figure 6 — Observed U.S. Temperature Change: This map shows the temperature changes for the U.S. from 1991-2012 compared to the 1901-1960 average (and compared to the 1951-1980 average for Alaska and Hawai'i). U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The bar graphs show the average temperature changes by decade for each region. The period from 2001-2012 was warmer than any previous decade in every region. The simplest way temperatures are recorded are from fixed land monitor stations around the country.

Figure 7 — Observed Increase in Frost-Free Season Length: This figure shows how the different regions in the United States have seen an increase in the frost-free season length. The frost-free season is defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall. An increase in the frost-free season length results in a similar increase in the growing season length. A longer growing season provides a longer period for plant growth and productivity, however in some cases where moisture is limited, the greater evaporation and loss of moisture can lead to less productivity because of increased drying and longer fire seasons.

Temperature Indicators Figure Set Descriptions (cont.)

Figure 8 — Peak Bloom Date for Cherry Trees Around Washington D.C.'s Tidal Basin: This figure shows the peak bloom date each year for cherry trees in Washington D.C. The peak bloom occurs when 70% of the blossoms are in full bloom. The shaded band shows the timing of the annual National Cherry Blossom Festival. Peak bloom date for cherry trees are occurring earlier than it did in the past. Since 1921, peak bloom dates have shifted earlier by approximately five days. The National Cherry Blossom Festival has continued to expand in length due to the earlier bloom dates.

Figure 9 — Ten Indicators of a Warming World: This figure shows some of the many indicators measured globally over many decades that demonstrate that the Earth's climate is warming. White arrows indicate increases, and black arrows show decreases. All the indicators expected to increase in a warming world are increasing, and all those expected to decrease in a warming world are decreasing.

Figure 10 — Global Average Sea Level Change: This graph shows changes in sea level for the world's oceans since 1880, based on a combination of long-term tide gauge measurements and recent satellite measurements. This figure shows average absolute sea level change, which refers to the height of the ocean surface, regardless of whether nearby land is rising or falling. As the temperature of the Earth changes, so does sea level. Temperature and sea level are linked for two main reasons: Changes in the volume of water and ice on land (namely glaciers and ice sheets) can increase or decrease the volume of water in the ocean and as water warms, it expands slightly—an effect that is cumulative over the entire depth of the oceans. Satellite data are based solely on measured sea level, while the long-term tide gauge data include a small correction factor because the size and shape of the oceans are changing slowly over time. (On average, the ocean floor has been gradually sinking since the last Ice Age peak, 20,000 years ago.) The shaded band shows the likely range of values, based on the number of measurements collected and the precision of the methods used.

Figure 11 — Reported Cases of Lyme Disease in the United States: This graph shows the annual incidence of Lyme disease, which is calculated as the number of new cases per 100,000 people. The graph is based on cases that local and state health departments report to Center for Disease Control's national disease tracking system. Lyme disease is a bacterial illness that can cause fever, fatigue, joint pain, and skin rash. Lyme disease is transmitted through the bite of certain species of infected ticks (referred to commonly as deer ticks) that carry the bacteria that cause Lyme disease. Climate is just one of many important factors that influence the transmission, distribution, and incidence of Lyme disease. However, studies provide evidence that climate change has contributed to the expanded range of ticks, increasing the potential risk of Lyme disease, such as in areas of Canada where the ticks were previously unable to survive.

Figure 12 — Change in Muir Glacier from 1941 & 2004: These pictures compare the Muir Glacier of Alaska in 1941 and 2004. From 1941 to 2004, the front of the glacier moved back about seven miles while its thickness decreased by more than 2,625 feet, according to the National Snow and Ice Data Center. Glacial retreat is one of the many indicators of a warming planet. While many glaciers have been retreating for quite some time, it is the rate of retreat that is concerning. The Muir glacier is just one of many examples of glacial retreat from around the world.

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods
Materials	Human Impact cards (1 set) Lesson 2 Worksheet 1: Claim, Evidence, Reasoning (1 for each student) Evidence Figure Set (1 set of 10 per group) Evidence Figure Set Descriptions (1 set) Lesson 2 Worksheet 2: Discussion Diamond (1 for each student) Separating Human and Natural Influences on Climate figure A large open area and chalk Small bag labeled 'What do humans do?'
Vocabulary	**greenhouse effect:** A phenomenon in which the atmosphere of a planet traps radiation emitted by its sun, caused by gases such as carbon dioxide, water vapor, and methane that allow incoming sunlight to pass through but retain heat radiated back from the planet's surface. **greenhouse gas:** gases which allow direct sunlight to reach Earth's surface, but absorb the infrared energy (heat) that is reradiated to the atmosphere. These gases include: water vapor, carbon dioxide, methane, nitrous oxide, among others. Also referred to as heat-trapping gases. **cumulative:** increasing or increased in quantity **atmosphere:** the mixture of gases that surrounds earth; the air **carbon dioxide:** CO_2, is the primary greenhouse gas emitted through human activities **emissions:** the act of producing or sending out something (such as energy or gas) from a source **carbon sink:** anything that absorbs more carbon that it releases (trees, ocean)
Student Learning Outcomes	• Students will be able to construct an argument, compare and critique multiple arguments, and analyze or interpret the facts presented. • Students will be able to investigate how temperature increase impacts and changes the atmospheric conditions. • Students will be able to demonstrate the greenhouse effect by showing how carbon dioxide and other greenhouse gases in the atmosphere trap heat and insulate the Earth. • Students will be able to determine how human population increase and per-capita consumption are contributing to the rise in the global temperature and the concentration of greenhouse gases in the atmosphere. • Students will be able to distinguish between the greenhouse effect and climate change.
Performace Expectation(s) addressed	**MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's system. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	**Greenhouse Effect Game:** • Print *Human Impacts Cards* and create 'What do humans do?' bag. • Find a large, open area for game play, preferably outside. Draw two concentric circles on the ground, one about 4 feet in diameter, and a larger one about 30 feet in diameter. The smaller circle represents the Earth and the larger one represents Earth's atmosphere. • Read the information about CER (Claim, Evidence, Reasoning) in the beginning of the curriculum guide. This will provide you will an understanding of how to implement and assess this form of argumentation. • Make copies of the *Evidence Figures and Evidence Figure Set Descriptions (if using)* for each group. • Make copies of the *Lesson 2 Activity: Claim, Evidence, Reasoning* worksheet for each student. • Make copies of the *Discussion Diamond* Worksheet for each student.

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes

Background Information

In this lesson, students will learn about the factors that are causing the climate to change. Students will be able to differentiate between natural and human causes that are happening around the world.

When discussing climate change, one of the most important concepts to understand is the greenhouse effect (see vocabulary section). The following is a list of important facts about the greenhouse effect and our atmosphere.

1. The earth's atmosphere has greenhouse gases which absorb and reflect the sun's radiation and keep the earth a habitable environment.
2. Some of the common greenhouse gases include carbon dioxide, methane, nitrous oxide, and water vapor.
3. Carbon dioxide is measured in parts per million (ppm) and reached 400 ppm in 2015. This is the highest that carbon dioxide levels hve been in recorded history. Furthermore, with ice core data, we can tell carbon dioxide levels have not been that high in 800,000 years.
4. The burning of fossil fuels and other human actions release carbon dioxide into the atmosphere. Fossil fuels are burned in the process of electricity production, industrial processes, driving vehicles, and more.
5. The increase in global temperatures is a result of the increase in carbon dioxide in our atmosphere, predominantly from humans burning fossil fuels. Scientists refer to this change in temperature which is influencing our climate system, as climate change.

> *The [temperature change] of the past 50 years is due primarily to human-induced increases in heattrapping gases. Human 'fingerprints' also have been identified in many other aspects of the climate system, including changes in ocean heat content, precipitation, atmospheric moisture, and Arctic sea ice.*
>
> *- U.S. Global Change Research*

The climate has always been changing. There are many factors influencing the climate. Changes in the earth's orbit and the tilt of the axis are examples of major influences. Others include changes in volcanic and solar activity. The current changes in earth's temperature are alarming because climate scientists know what the earth should be doing, based on where the earth is at in those cycles of orbital variation and other factors. Only when human effects are taken into account does the actual temperature data match.

Students will be participating in a game in this lesson that will help them understand how the greenhouse effect keeps the planet warm, but also is causing our atmosphere to warm too quickly. The following is a list of things the students should learn during the game:

a. There are gases in the atmosphere (CO_2, methane, nitrous oxide, etc.).
b. These gases have different properties (lifetime, percentages).
c. They absorb, radiate, reflect sunlight/energy differently.
d. These gases are keeping Earth habitable.
e. The greenhouse effect is not as simple as one gas. It is a cumulative effect of many gases and the amounts of those gases.
f. The natural greenhouse effect is being enhanced by the increase in CO_2, causing a rise in global temperature. This enhanced greenhouse effect is referred to as climate change.

In this lesson educators have the opportunity to assess how the modeling activities (the game), the analogies (the cake) and the mathematical models (graphs) develop and change student mental models.

Lesson 2: What factors have caused the rise in the global temperature over the last century?

Looking into the causes

Journal Assignment

By the end of this lesson students will have a detailed picture of the greenhouse effect and statements about the *Human and Natural Influences on Climate* graph.

Activity Description

Introduction:

1. Refer back to the figure that was assembled in Lesson 1: Global Land and Ocean Temperature Anomalies graph. Discuss why the graph looks like it does. What things have happened in the past 135 years that could cause the global temperature changes that you see? Make a list of items (keep it accessible because students will need to come back to it at the end of this lesson).
2. Watch the following video about carbon dioxide, the greenhouse effect, and heat-trapping gases: http://www.climategen.org/ngconline. After the video, ask students to reflect in their journals on the questions:

    a. Why is the greenhouse effect important?
    b. Why is CO_2 important?
    c. What is the relationship between CO_2 and the greenhouse effect?

3. Use the following analogy to explain what can happen if the ingredients to the atmosphere are changed. Cake as weather: "Let's say a storm (weather) is like a cake. A storm has a specific set of ingredients, which the atmosphere provides. If we don't have the ingredients, we are not going to make a cake. A storm needs air masses to collide and rise, allowing water to condense and fall out as rain. A cake needs a combination of flour, eggs, butter and sugar. Now what happens if we change the ingredients slightly? Say we use whole wheat flour, which makes the cake more dense. Or we use more sugar, which makes it sweeter. We will still make a cake, but it will be different. Changing the ingredients doesn't change the fact that you are making a cake, just how it turns out. This is what climate change does. Climate change doesn't make the storm (or cake), but it changes the ingredients! The cake will turn out a bit different."

Activity 1: The Greenhouse Effect Game

Teacher Instructions: This activity is about making a model of the atmosphere and facilitating discussion. Students will illustrate a diagram of the greenhouse effect throughout the game. In the student's drawings there will need to be arrows representing where light, heat, energy, etc. are coming from. As a teacher, these are things you should not instruct your students to do, but highlight as you review their work and as they improve their diagrams after each round of game play. "How did you show movement? Heat? Light? Amount?" Encourage them, "I like how you used arrows to show direction/amount/etc." The game will work best with 15-30 students.

Setup (see Background Information)

1. Have students each make two notecards. One says HEAT and the other LIGHT.
2. Before going outside, have students draw a diagram of the greenhouse effect in their journals. Be sure they label what they draw, even if it is only a few things. They need to bring their journals outside to draw after each round of the game.
3. Take students outside to play the game. Explain that the smaller circle represents the Earth and the larger one represents Earth's atmosphere. Have students place their 'heat' cards in a pile on the Earth. Explain to students that the size to atmosphere is not to scale. In real life the Earth's diameter is 7,917 miles and the atmosphere reaches about 800 miles above the Earth. A good analogy would be a peach. The flesh would represent the earth and the skin would represent the atmosphere.

Play (Take it Outside)

Round 1: Natural greenhouse effect.

a. Choose two students to be CO_2 molecules, and place them anywhere in the Earth's "atmosphere." Once they are in the atmosphere they cannot move their feet. The other students are sunlight (energy) from the sun.

b. The object of the game is for the sunlight to enter the atmosphere, tag the Earth, exchange their 'light' card for a 'heat' card, and then escape the atmosphere without getting tagged by a CO_2 molecule. Students can only be tagged once they become heat (after they tag the earth and exchange their cards). This simulation recreates the greenhouse effect: energy from the sun is trapped as heat by CO_2 and other gases in the atmosphere. Sunlight who are tagged must stay standing still in the atmosphere. Those who avoid being tagged bounce back out of the atmosphere into space. The round lasts approximately 30 seconds.

c. After the first round, have the escaped sunlight form a circle around the atmosphere to check how much heat has been trapped by greenhouse gases. During the first round, most of the energy will have escaped the atmosphere because CO_2 levels are low. Discuss how this may affect the temperature of the planet. Remind students that a certain amount of CO_2 is necessary to keep the planet consistently warm enough to support life. Before continuing the game, clear all the trapped sunlight (heat) out of the atmosphere.

d. After round one, give students several minutes to add or change their diagrams and give them time to journal about what they learned about the greenhouse effect. What would they change about their initial diagram?

Round 2: Human enhanced greenhouse effect.

a. Increase the number of CO_2 molecules in the atmosphere. Do this by reaching into the "What do humans do?" bag and pulling out an action card (for this round, include only cards that add CO_2 to the atmosphere). Follow the directions on the card and play again. Give time to journal and draw after round 2.

Round 3: Slowing down the greenhouse effect.

a. Put all of the action cards in the bag so that CO_2 levels will increase and decrease based on the actions taken. Discuss what happens with each draw (2-3 cards). Some cards will not increase or decrease CO_2 levels. Riding your bike instead of driving will not add CO_2, but it won't take away CO_2 either.

b. Give time to journal and draw after round 3. How did students' idea of the greenhouse effect change throughout the game? What conclusions can be drawn?

Activity 1: Wrap-up

Have a discussion about how energy from the sun gets trapped in the Earth's atmosphere. Discuss how human actions, particularly burning fossil fuels, can enhance the greenhouse effect by putting more CO_2 into the atmosphere. This increase in CO_2 which is increasing global temperature is referred to as climate change. The game should demonstrate that when you increase the amount of CO2, more heat gets trapped (illustrated by the students that were tagged in the atmosphere) and the Earth warms up. The action cards demonstrate how even small-scale actions can affect the amount of greenhouse gas that we emit to the atmosphere. The game can be a springboard into a variety of other explorations such as researching alternative energy sources, discussing sustainable lifestyles, and examining the different choices humans can make.

a. How was this game like the atmosphere/not like the atmosphere?
b. What makes the game an accurate or inaccurate model of the atmosphere?
c. How did your diagram change throughout the game? What did you learn during the game?
d. How did you show things moving around? How did you show quantity? How did you show that light changes to heat?

Activity 2: Claim, Evidence, Reasoning

1. Introduction: When asked about climate change, most people are able to give an opinion such as, "I believe...". This activity is going to help students get away from saying "I believe..." and instead say, "Based on the data...". To accomplish this change of thinking students will be using an argumentation strategy known as Claim, Evidence, Reasoning (see information at beginning of curriculum for explanation and help implementing CER).
2. Students will be working in small groups to read figures from various sources to help answer this question: What is causing the global average temperature on Earth to increase? Based on what they know already, students will make a claim, collect evidence, and build an argument based on their analysis of the figures.

   a. Put students in groups of 3-4. Hand out a set of Evidence Figures for each group and a Claim, Evidence, Reasoning worksheet for each student. In their groups, students will study each figure and write a brief summary statement of what is being shown. What is the main concept or point being conveyed by the figure? Be sure to use the example format for your answers.
   b. Using the information you summarized, make a claim that answers the question: What is causing the global average temperature on Earth to increase? (Ex: Global temperatures have risen over the past century because there are more hot air balloons.)
   c. Give evidence to support your claim. Provide scientific data from the figures and data you were given. Include specific pieces of data. Students will also think about data they feel is missing.
   d. Give reasoning to explain why your evidence supports your claim. Why is your evidence important? Describe what it means that Earth's temperature is rising and why your evidence allowed you to determine that the Earth is warming because of those reasons.
   e. After giving evidence and reasoning, would you revise your claim? Is there more info that you need? Write a statement about how you would revise your claim.

   Note: Teachers may decide to share the explanatory information given in the Evidence Figure Set Descriptions with students after they have made their own interpretations.

3. When students are finished with their worksheets, put students into groups of 5. Pass out the Discussion Diamond worksheet. Use the discussion diamond worksheet. In the center each student should write, "What is causing a rise in global temperatures?" Each partner will present their claim and then the rest of the group will write the claim and the lines of evidence provided in one triangle. Students should develop two clarifying questions based on their notes and ask the presenter. By the end of the presentations, students will each have a summary of the claims and evidence.
4. Students should discuss using similar or different evidence and if/how other group members use of evidence altered their own claim.

Conclusion

1. Show the *Separating Human and Natural Influences on Climate* figure to your students on page 50 or by visiting the website: http://nca2014.globalchange.gov/report/our-changing-climate/observed-change.
2. In their notebooks, ask students to write their interpretation of the figure. What do each of the lines/colors mean? What are the contributing factors to those lines? Thinking about the other figures you reviewed, what connections can you make to this figure? Bring out the list of items that were discussed in the introduction activity.

   a. Figure Description: Observed global average changes (black line), model simulations using only changes in natural factors (solar and volcanic) in green, and model simulations with the addition of human-induced emissions (blue). Climate changes since 1950 cannot be explained by natural factors or variability, and can only be explained by human factors.
3. Invite groups to share their explanation of the figure and the connections they made.

Extensions

1. Visit Climate Generation's Our Changing Climate curriculum for grades 6-12 for three readings: The Structure of the Atmosphere, Heat-Trapping Gases in the Atmosphere, and The Greenhouse Effect at http://curriculum.climategen.org/2015/OCC_6-12_L1_AtmosphereReadings.pdf. These will help students understand more about the greenhouse effect and heat-trapping gases.
2. Ask students to pursue a line of evidence for the increase in global temperatures that interests them and find some authentic data they can graph themselves and present to their peers. Sources of data that relate to climate change include:

Data Enhanced Investigations for Climate Change Education — http://dicce.sri.com/

NOAA Earth Monitoring — http://www.esrl.noaa.gov/gmd/

CoCoRaHs — http://www.cocorahs.org/ViewData/

National Centers for Environmental Information — https://www.ncdc.noaa.gov/data-access

NASA Data — http://data.giss.nasa.gov/

Globe Phenology Data — http://www.globe.gov/globe-data/visualize-and-retrieve-data

References

The Greenhouse Effect Game was adapted with permission from Green Teacher #70, Summer 2003. Subscriptions to this non-profit magazine are available from www.greenteacher.com or by calling toll free 1-888-804-1486.

Activity 2: Claim, Evidence, Reasoning was adapted with permission from Barry Golden. Original article (Generating arguments about climate change) from Science Scope, 2012.

CER Worksheet Adapted from Katherine L. McNeill and Dean M. Martin's article in Science & Children, 4/ 2011

Cake as weather anology adapted from Angus Ferraro:
https://angusferraro.wordpress.com/2012/11/19/storms-are-like-cake-analogies-for-weather-and-climate/

Carbon dioxide video credit: courtesy of NASA and the National Science Foundation.

Humans drive cars.
Every gallon of gas puts 18.8 lbs of CO_2 into the atmosphere.

Add four CO_2 molecules

Humans ride bikes. Riding a bike is the most energy efficient form of transportation and it's free!

DON'T add two CO_2 molecules

Humans cut down trees.
Trees remove CO_2 from the atmosphere during photosynthesis.
Fewer trees means more CO_2.

Add two CO_2 molecules

Humans create energy efficient technology.

DON'T add two CO_2 molecules

Humans drive more cars.
In 1906 Ford built the Model T car. Between 1906 and 1927 15 million cars were sold. Today, an estimated 500 million are in use worldwide.

Add four CO_2 molecules

Humans plant trees.
Trees remove CO_2 from the atmosphere during photosynthesis.
More trees means less atmospheric CO_2.

Remove two CO_2 molecules

Humans burn trash.
Burning waste puts CO_2 into the atmosphere along with other pollutants.

Add two CO_2 molecules

Humans recycle.
Recycling saves energy, reducing our use of fossil fuels.

DON'T add two CO_2 molecules

Agriculture activities (N_2O)
Pesticides and unsustainable farming practices increase nitrous oxide into the atmosphere.

Add two CO_2 molecules

Humans use wind and solar.
Renewable energy doesn't add CO_2 or other greenhouse gases to the atmosphere.

DON'T add two CO_2 molecules

Name ______________________________

Student Worksheet: Claim, Evidence, Reasoning

In this activity you will write a claim to answer the question: What is causing the global average temperature on Earth to increase?

A. For each figure, write a brief summary statement of what is being shown. What is the main concept or point being conveyed by the figure? Be sure to use the example format for your answers.

Ex) Figure 5 shows the carbon emissions from burning coal, oil, gas, and producing cement from 1850 to 2012. All areas are showing an overall increase in emissions with the total carbon emissions totaling over 8,000 million metric tons.

1. Graph Title: ____

Summary

2.Graph Title: ____

Summary:

3. Graph Title: ____

Summary

4. Graph Title: ____

Summary

5. Graph Title: ____

Summary

6. Graph Title: ____

Summary

7. Graph Title: ____

Summary

8.Graph Title: ____

Summary:

9. Graph Title: ____

Summary

10. Graph Title: ____

Summary

B. Using the information you collected, make a claim to answer the question: What is causing the global average temperature on Earth to increase? Ex) Global temperatures have risen over the past century because there are more hot air balloons.

Claim:

C. Give evidence to support your claim. Provide scientific data from the graphs and data you were given. Include specific pieces of data.

Evidence:

D. Is there any information you feel like you're missing? Explain.

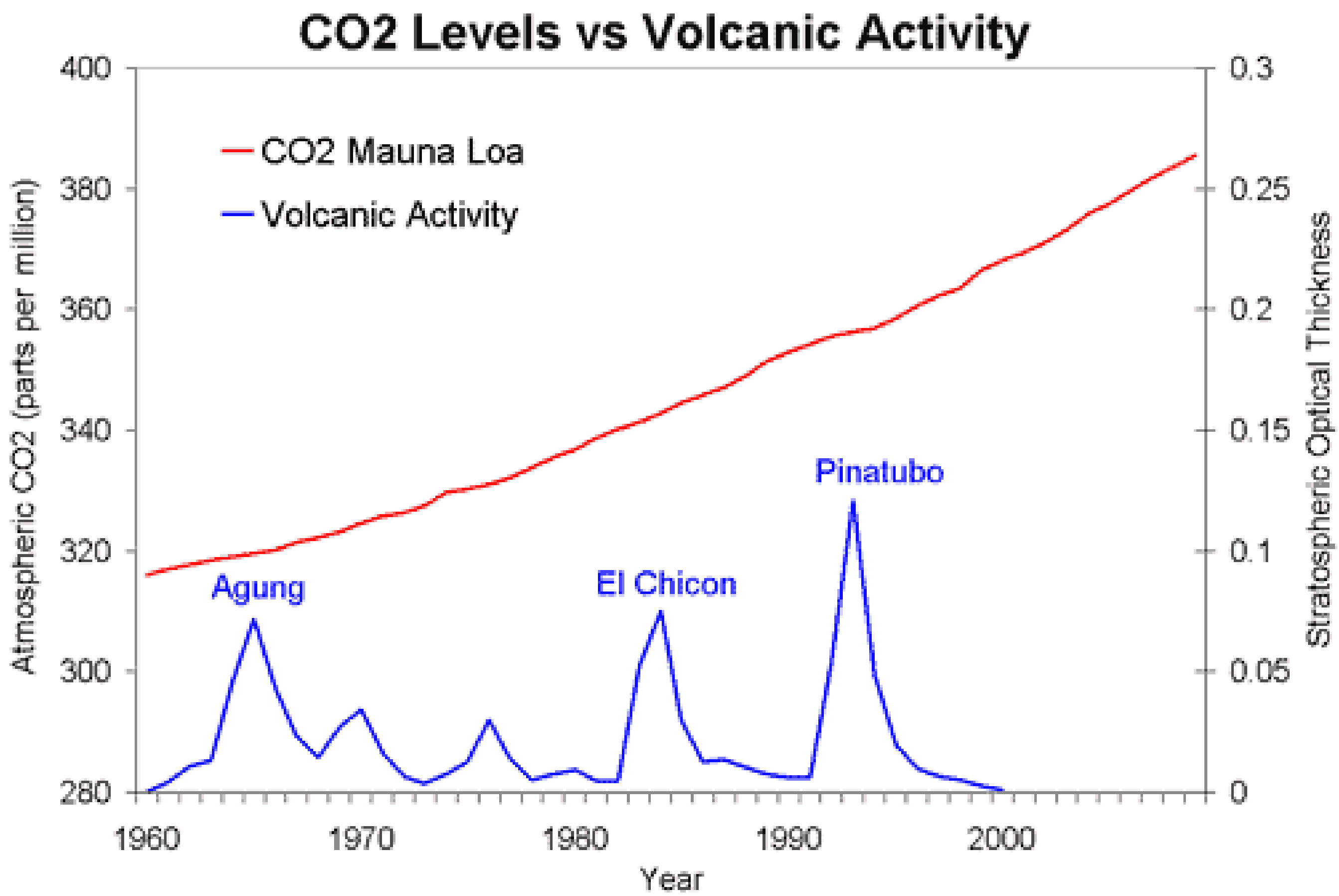
E. Give reasoning to explain why your evidence supports your claim. Why is your evidence important? Describe what it means that Earth's temperature is rising and why your evidence allowed you to determine that the Earth is warming because of those reasons.

Reasoning:

F. After giving evidence and reasoning, would you revise your claim? Is there more info that you need?

Revise:

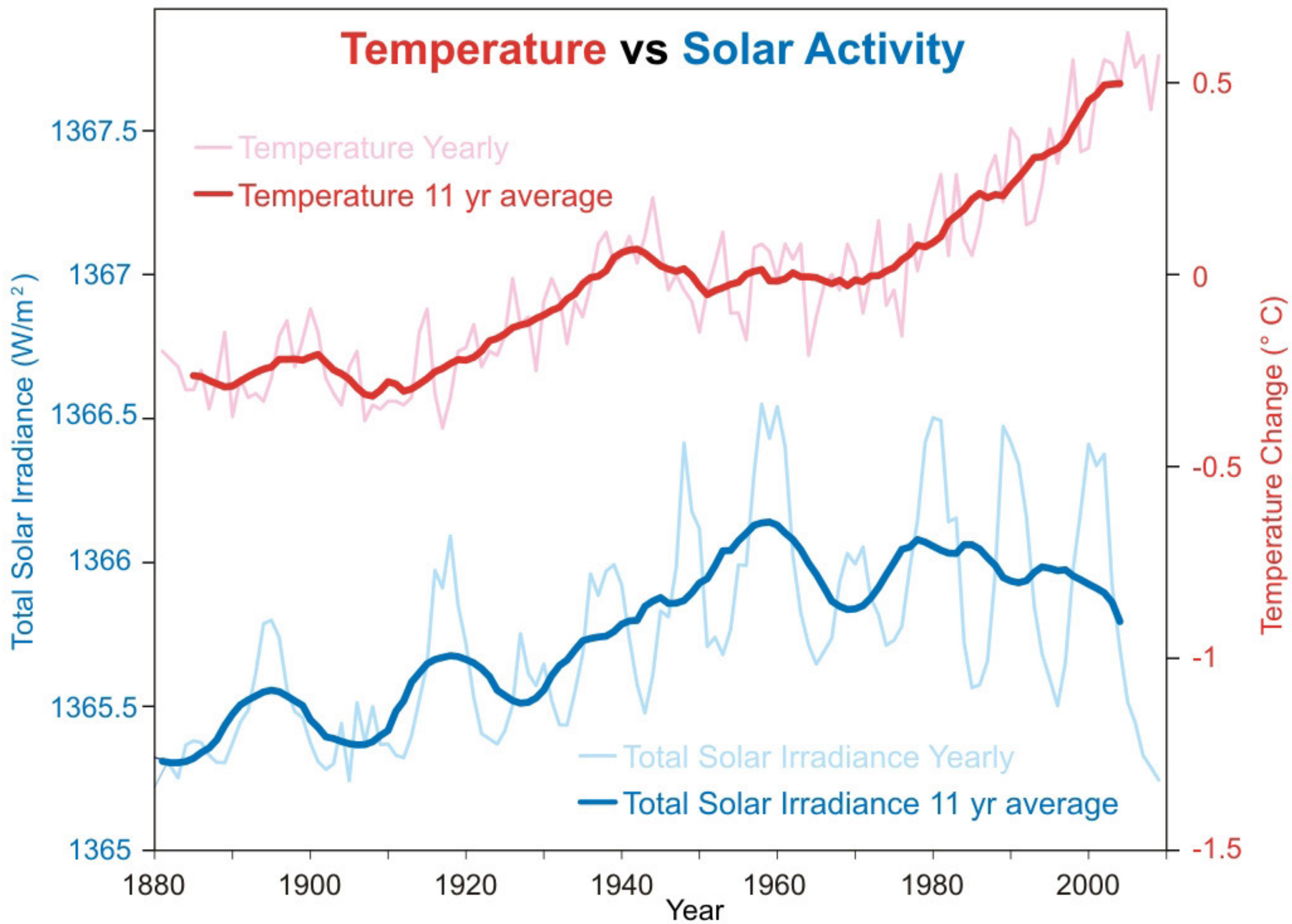
Figure 1 — CO_2 Levels vs. Volcanic Activity



Note: Stratospheric Optical Thickness is the measure of aerosols (e.g., urban haze, smoke particles, desert dust, sea salt) distributed within a column of air from the instrument (Earth's surface) to the top of the atmosphere.

Skeptical Science. (2015). *Do volcanoes emit more CO2 than humans?* Retrieved from www.skepticalscience.com/print.php?r=50

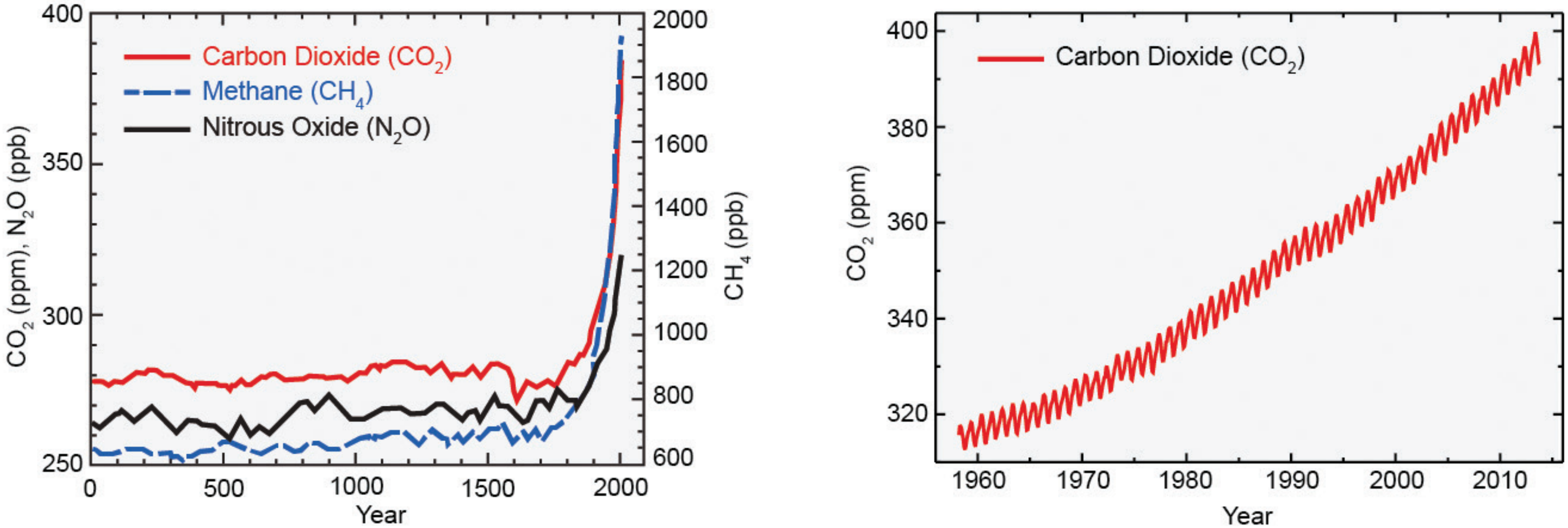
Figure 2 — Temperature vs. Solar Activity



Note: Total Solar Irradiance is the power per unit area produced by the Sun.

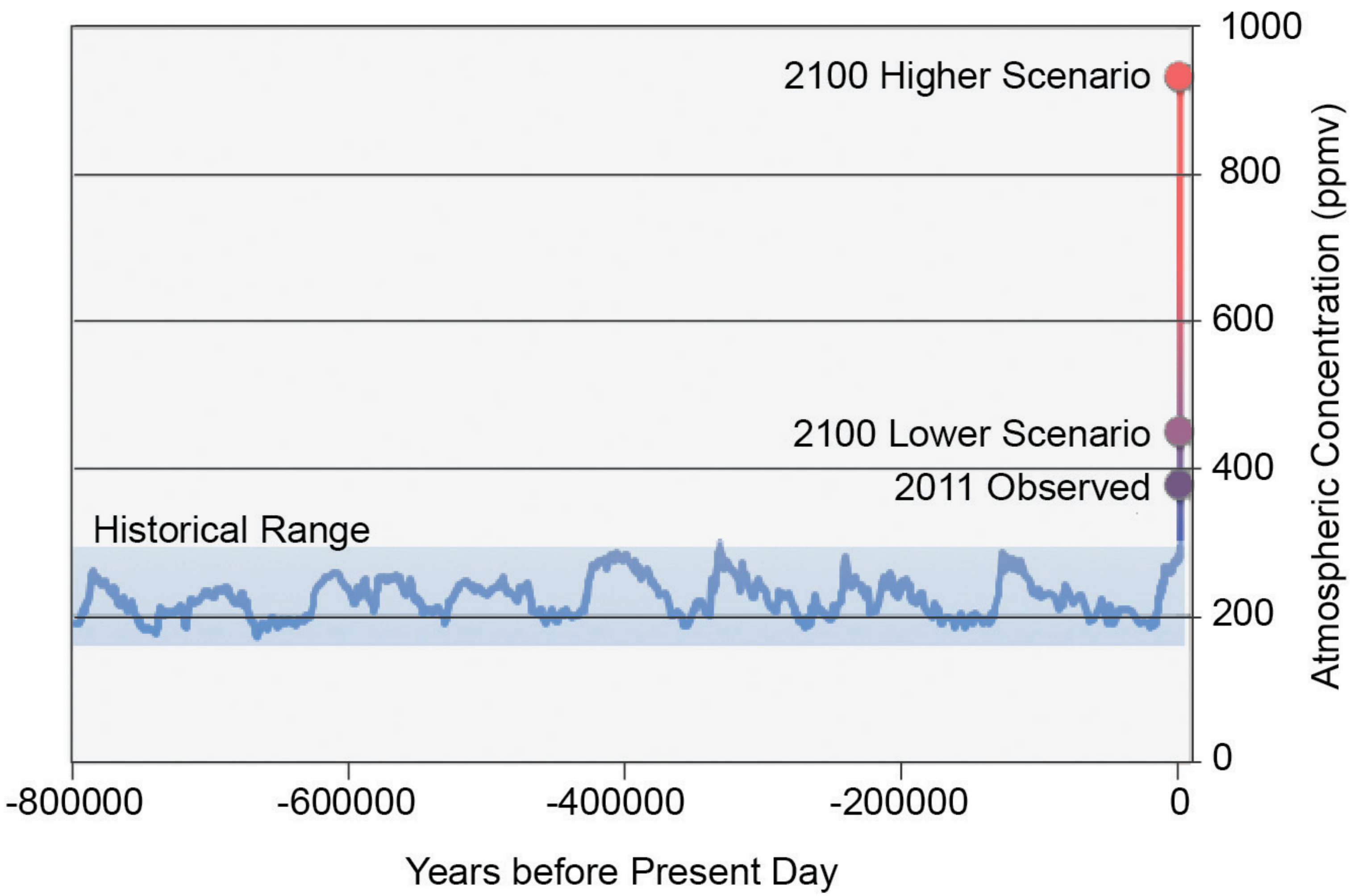
Skeptical Science. (2015). *Sun & climate: moving in opposite directions.*
Retrieved from https://www.skepticalscience.com/solar-activity-sunspots-global-warming.htm

Figure 3 — Heat-Trapping Gas Levels



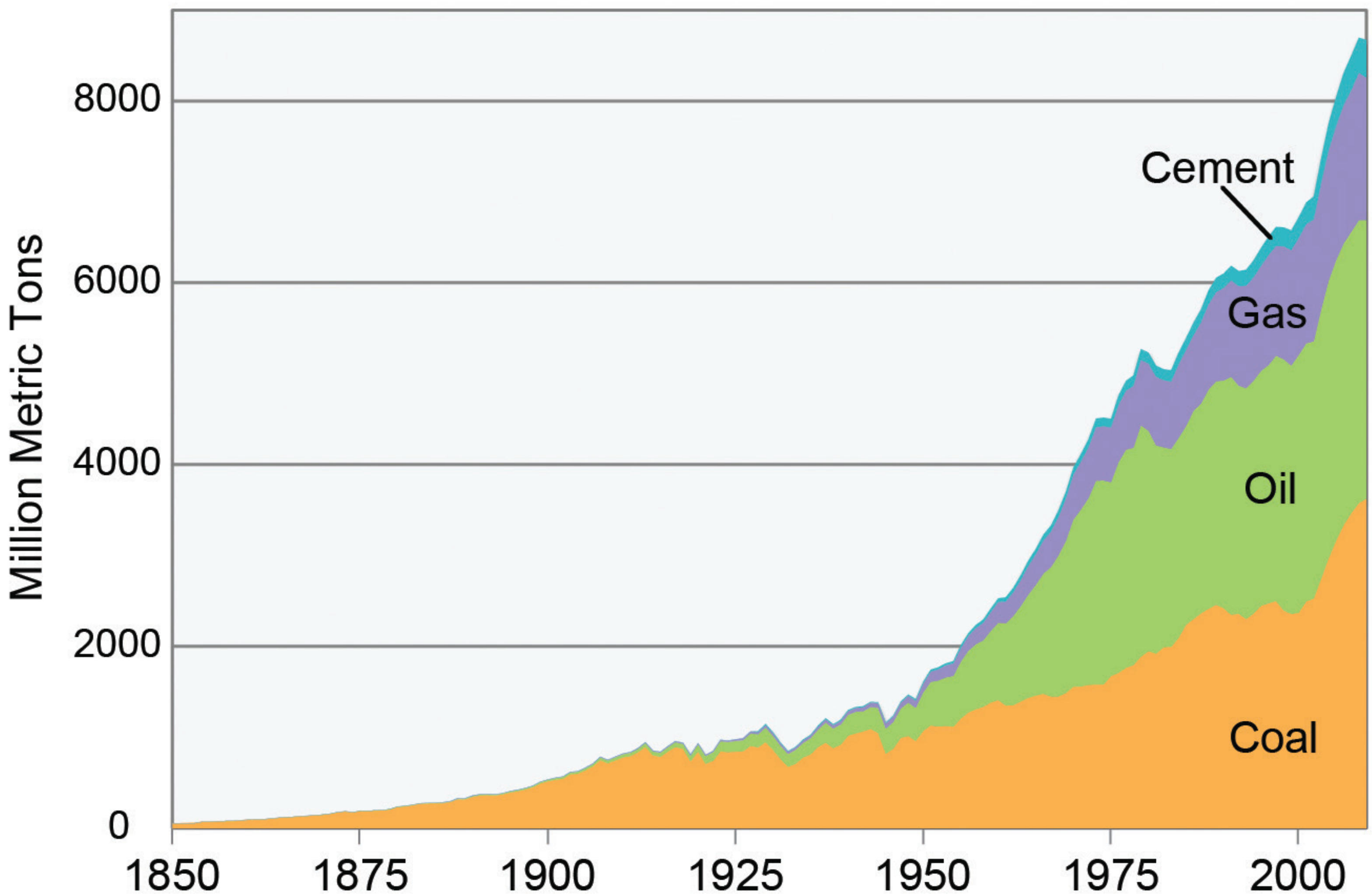
National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement*.
Retrieved from http://nca2014.globalchange.gov/report/appendices/climate-science-supplement
Source: Adapted from: Climate Change 2013: The Physical Science Basis

Figure 4 — Atmospheric Carbon Dioxide Levels



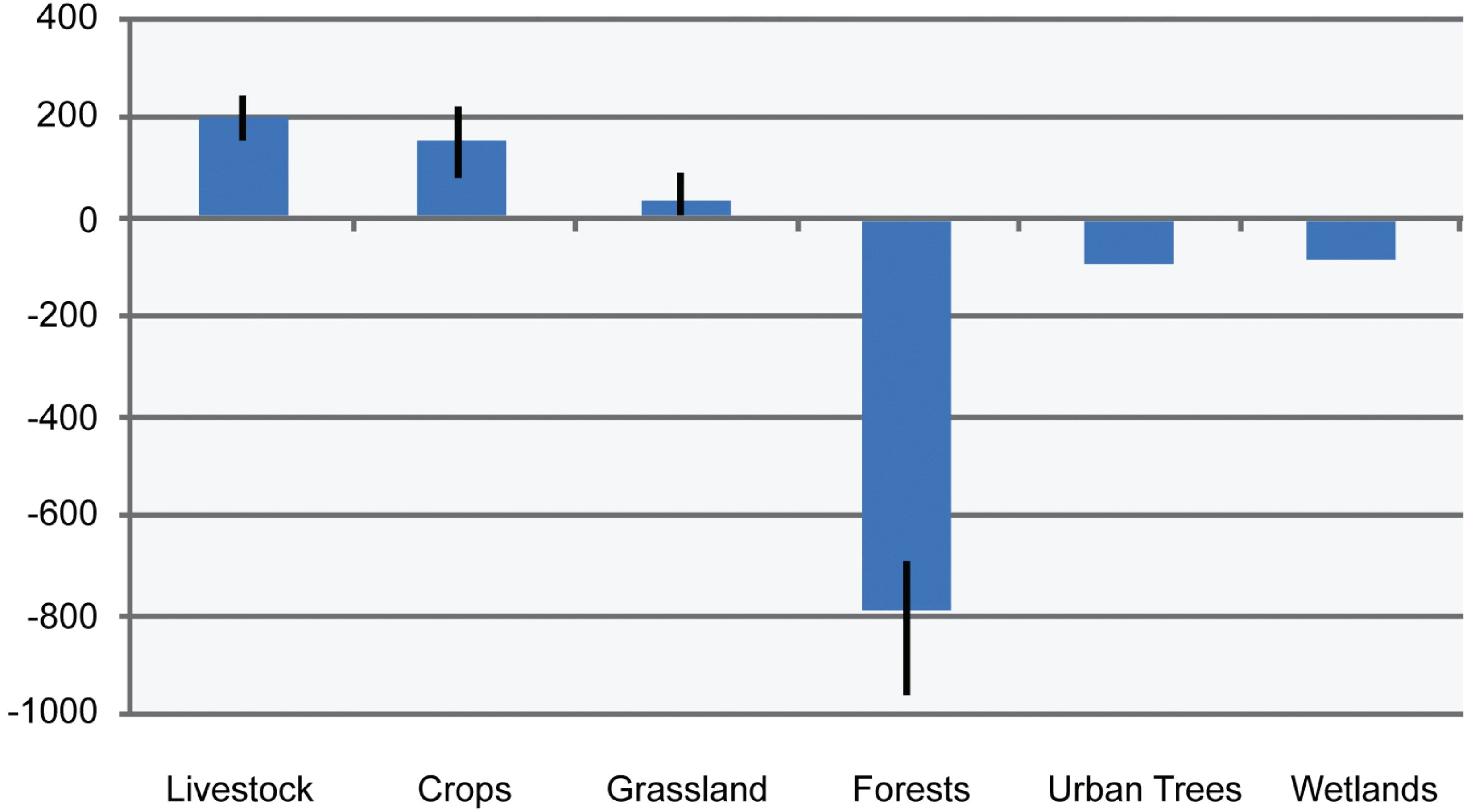
National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement.* Retrieved from http://nca2014.globalchange.gov/report/appendices/climate-science-supplement
Source: Katharine Hayhoe, Texas Tech University

Figure 5 — Carbon Emissions in the Industrial Age



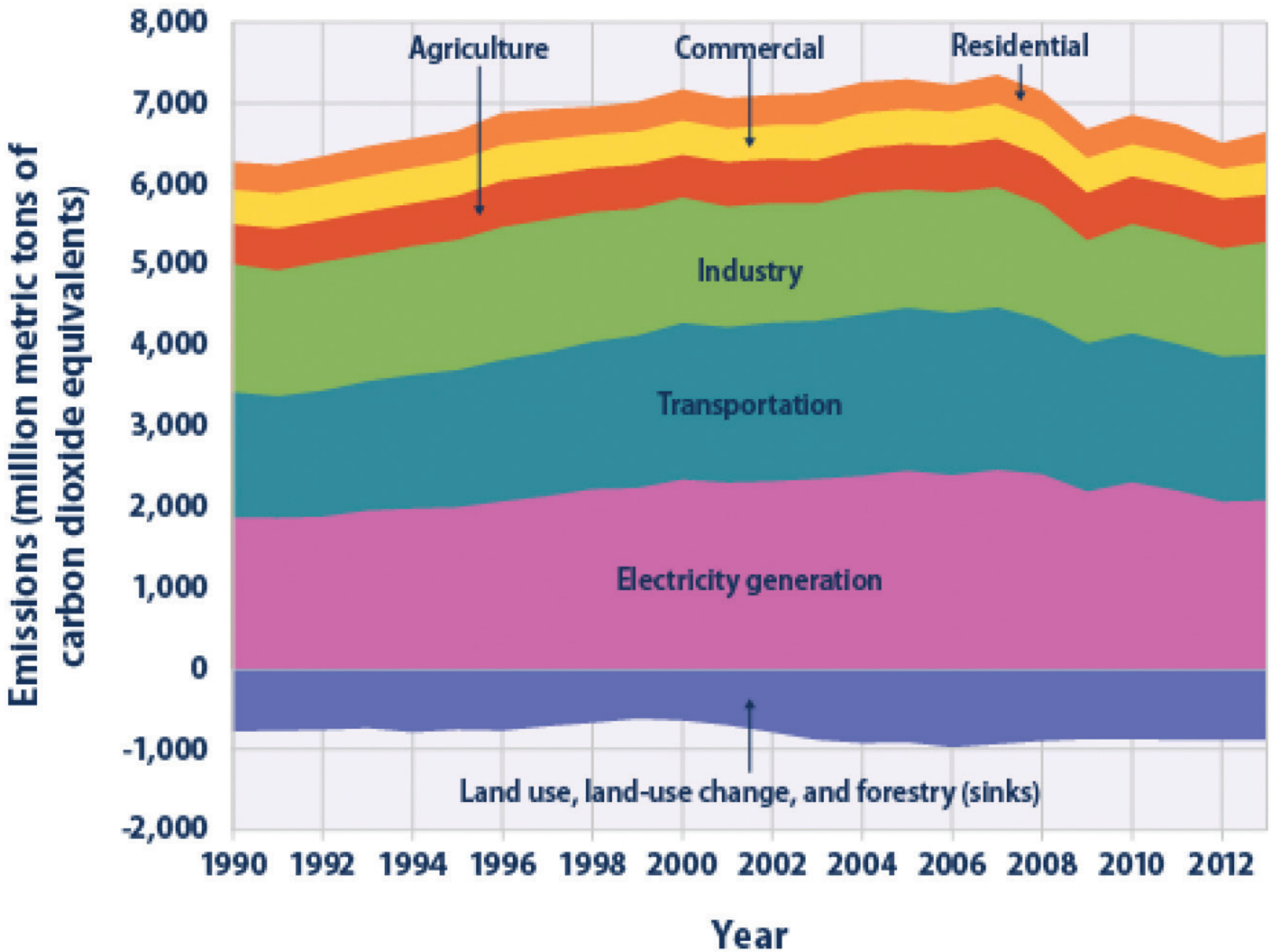
National Climate Assessment and Development Advisory Committee. (2014). *Climate Science Supplement.* Retrieved from http://nca2014.globalchange.gov/report/appendices/climate-science-supplement
(Source: Katharine Hayhoe, Texas Tech University)

Figure 6 — Sources and Sinks in U.S. Agriculture and Forests



National Climate Assessment and Development Advisory Committee. (2014). *Mitigation.*
Retrieved from http://nca2014.globalchange.gov/report/response-strategies/mitigation#graphic-17171

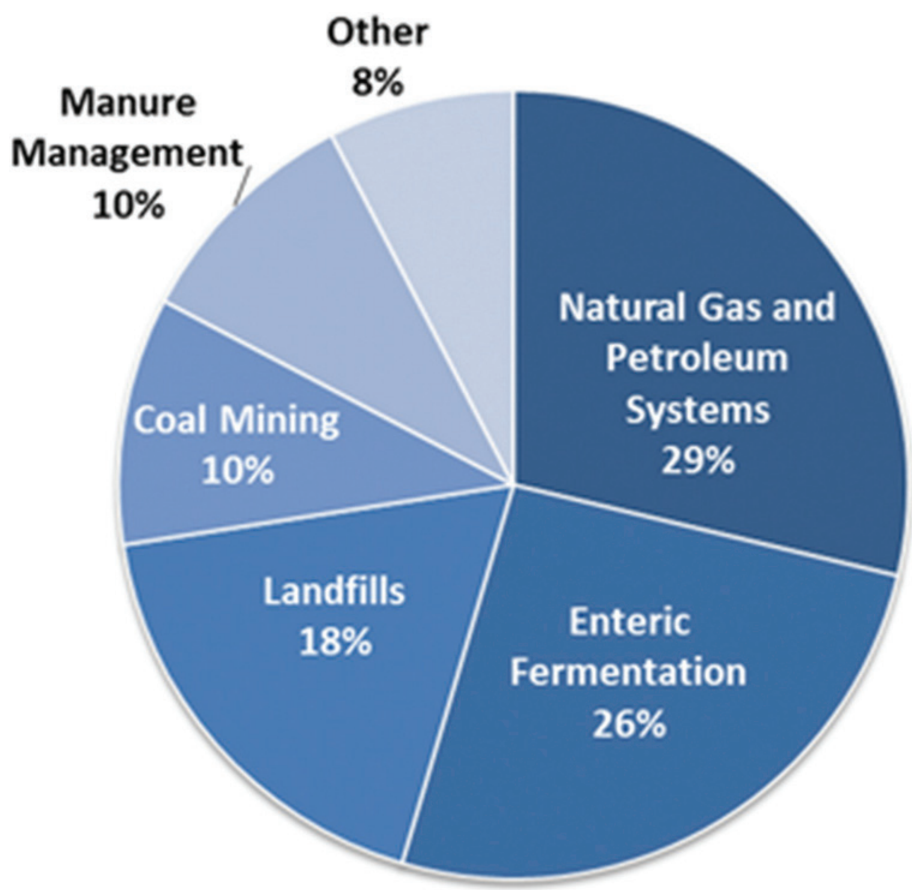
Figure 7 — U.S. Greenhouse Gas Emissions and Sinks by Economic Sector



Data source: U.S. EPA (U.S. Environmental Protection Agency). 2015. Inventory of U.S. Greenhouse gas emissions and sinks: 1990-2013. EPA 430-R-15-004.www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

U.S. Environmental Protection Agency. (2015). *Climate Change Indicators in the United States.* Retrieved from http://www.epa.gov/climatechange/science/indicators/ghg/us-ghg-emissions.html

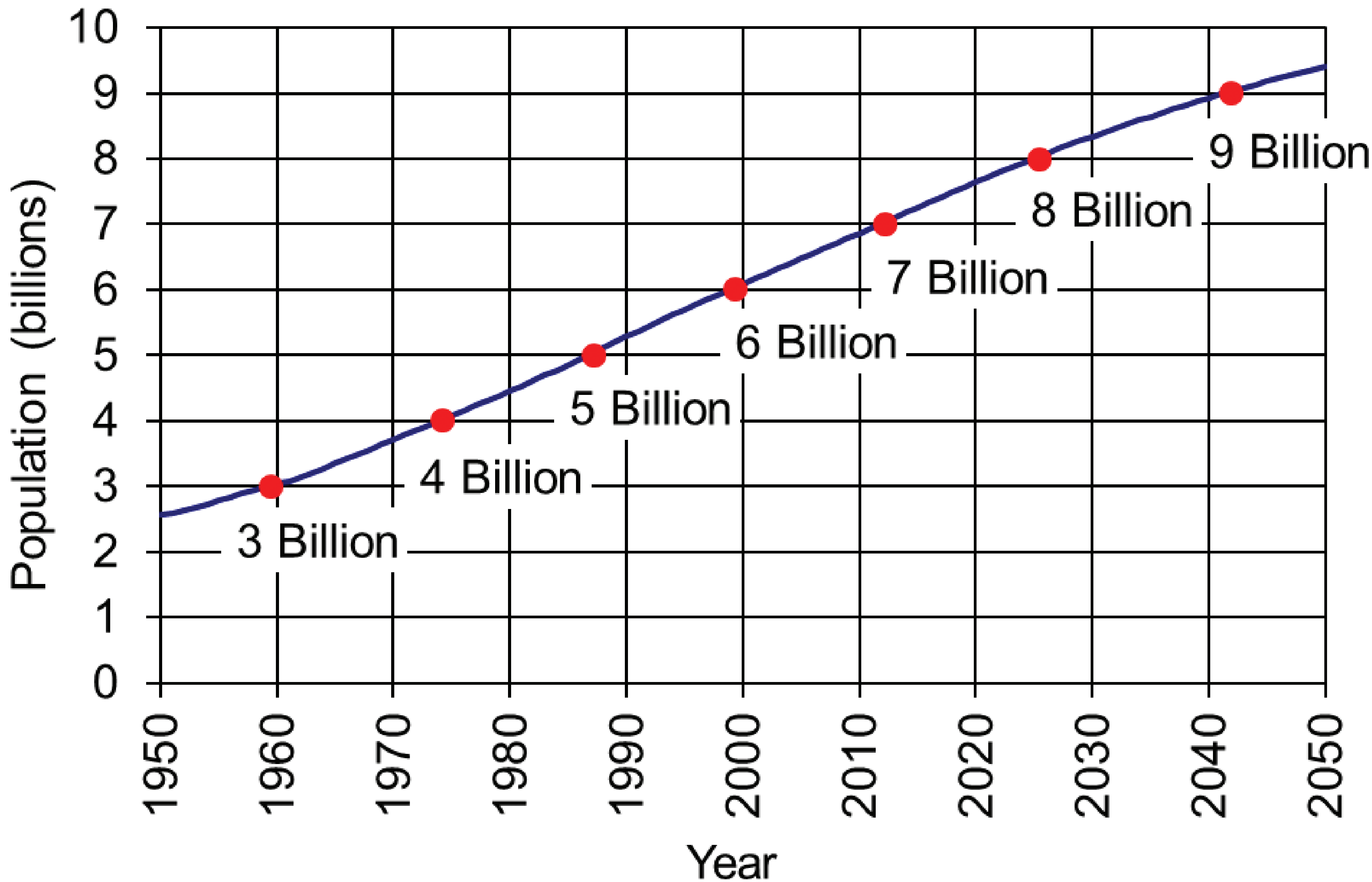
Figure 8 — U.S. Methane Emissions, by source



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013.*

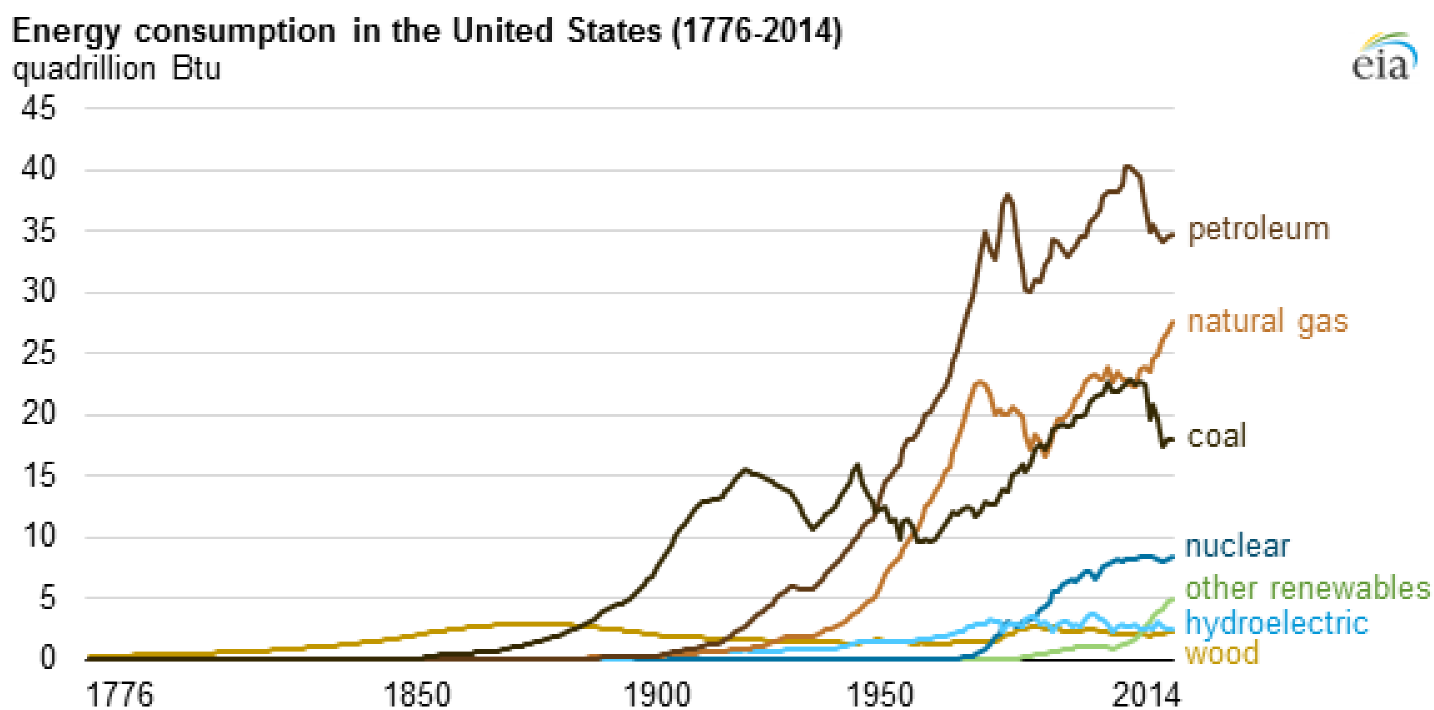
U.S. Environmental Protection Agency. (2015). *Overview of Greenhouse Gases.* Retrieved from http://epa.gov/climatechange/ghgemissions/gases/ch4.html

Figure 9 — World Population: 1950-2050



U.S. Census Bureau. (2015). *International Programs.*
Retrieved from https://www.census.gov/population/international/data/idb/worldpopgraph.php

Figure 10 — Energy Consumption in the United States (1776-2014)



U.S. Energy Information Agency. (2015). *Today in Energy.*
Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=21912
(Source: U.S. Energy Information Administration, Monthly Energy Review)

Evidence Figure Set Descriptions

1. CO_2 Levels vs. Volcanic Activity — Volcanoes emit CO_2 both on land and underwater. Underwater volcanoes have little effect on atmospheric CO_2 levels. Land volcanoes are estimated to emit 242 million tons of CO_2 per year. In contrast, humans are currently emitting around 29 billion tons of CO_2 per year. Human CO_2 emissions are over 100 times greater than volcanic CO_2 emissions. When comparing atmospheric CO_2 levels to volcanic activity, it is apparent that large volcanic eruptions have little impact on CO_2 levels.

2. Temperature vs. Solar Activity — Over the last 35 years the sun has shown a slight cooling trend. However global temperatures have been increasing. Since the sun and climate are going in opposite directions scientists conclude the sun cannot be the cause of recent global warming (climate change). The only way to blame the sun for the current rise in temperatures is by cherry picking the data. This is done by showing only past periods when sun and climate move together and ignoring the last few decades when the two are moving in opposite directions.

3. Heat-Trapping Gas Levels — Current atmospheric levels of carbon dioxide, methane, and nitrous oxide are notably higher than their pre-industrial (1750) averages. Air sampling from 1958 shows the steady increase in CO_2, which has been largely influenced by humans. The increases and decreases in the Carbon Dioxide graph is caused by seasonal changes in the Northern Hemisphere. As the leaves come out in the spring, they capture more CO_2 from the atmosphere. In the winter they lose their leaves and are not able to capture the CO_2 and therefore, the amount of CO_2 in the atmosphere goes up.

4. Atmospheric Carbon Dioxide Levels — Air bubbles trapped in ice cores can be examined to help scientists determine what the atmosphere was like many years ago. Ice core data goes back 800,000 years, and only recently has the CO_2 level increased to 400 parts per million (ppm). Before human activity, CO_2 levels fluctuated between 170 and 300 ppm. By 2100, additional emissions from human activities are projected to increase CO_2 levels to 420 ppm (Lower Scenario), which would require immediate and sharp emissions reductions. If we continue to increase our emissions, the Higher Scenario predicts that we will reach 935 ppm by 2100.

5. Carbon Emissions in the Industrial Age — This figure shows global carbon emissions from burning coal, oil, and gas and producing cement. These emissions account for about 80% of the total emissions of carbon from human activities. Land-use changes (like cutting down forests) accounts for the other 20% in recent decades. Land-use changes increases total emissions because the carbon that was stored in a tree is released after the forests are cut down.

6. Sources and Sinks in U.S. Agriculture and Forests — This figure shows the annual average greenhouse gas emissions from land use including livestock and crop production, but does not include fossil fuels used in agricultural production. Forests are a significant "sink" that absorbs CO_2 from the atmosphere. Urban trees and wetlands are also sinks. As we cut down more and more forests, we are not only adding the carbon that was captured in the trees, but we are also unable to capture any more carbon in the future.

Evidence Figure Set Descriptions (cont.)

7. U.S. Greenhouse Gas Emissions and Sinks by Economic Sector — This figure shows greenhouse gas emissions and sinks by source in the United States from 1990 - 2012. The only sinks are land-use sinks, like forests and wetlands. Notice how there are many more sources of emissions than sinks. In order to decrease emissions, the negative values must be closer to the positive values in order to cancel each other out.

8. U.S. Methane Emissions — This pie chart shows the U.S. methane emissions by source. Methane (CH_4) is the second most prevalent greenhouse gas emitted in the United States from human activities. Methane accounts for about 10% of all U.S. greenhouse gas emissions. Methane is also emitted by natural sources, such as wetlands. Methane's lifetime in the atmosphere is much shorter than CO_2, but methane is a much stronger greenhouse gas. Globally, over 60% of total CH_4 emissions come from human activities. (Enteric Fermentation is a process that takes place in the stomachs of livestock animals and leads to the animal passing gas and releasing methane.)

9. World Population: 1950-2050 — The world population increased from 3 billion in 1959 to 6 billion by 1999, a doubling that occurred over 40 years. The Census Bureau's latest projections imply that population growth will continue into the 21st century, although more slowly. The world population is projected to grow from 6 billion in 1999 to 9 billion by 2044, an increase of 50 percent that is expected to require 45 years.

10. Energy Consumption in the United States (1776-2014) — This graph shows the energy consumption of the U.S. from 1776 to 2014. Nonrenewable resources like coal, natural gas, and oil have created most of the energy for the U.S. over the nation's history. But new forms of energy— nuclear— and renewable forms of energy—wind, solar, geothermal, and biomass— have started to provide a larger share of the U.S. energy consumption. The total amount of energy consumed continues to rise overall because of increased population. Notes: a BTU (British Thermal Unit) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at a specified temperature.

Discussion Diamond Worksheet

Name:

Date:

Name:

Date:

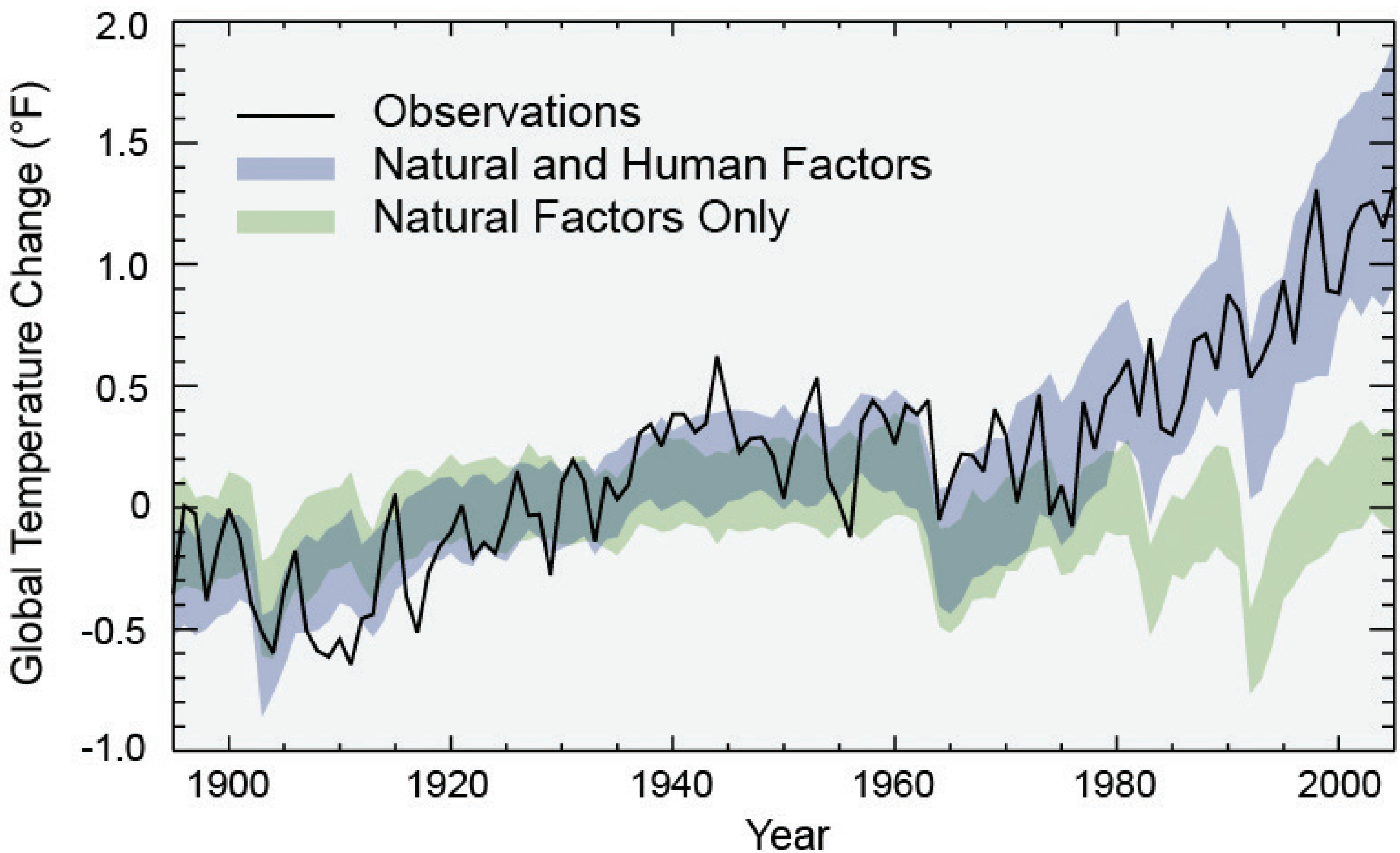
Name:

Date:

Name:

Date:

Separating Human and Natural Influences on Climate



National Climate Assessment and Development Advisory Committee. (2014). *Observed Change*. Retrieved from http://nca2014.globalchange.gov/report/our-changing-climate/observed-change
(Figure source: adapted from Huber and Knutti)

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods (2 days if presentations are skipped)
Materials	Ten Indicators of A Warming World graphic Climate Change Repercussions Research Project (1 for each student) National Climate Assessment Scavenger Hunt (1 for each student) Student computers or access to ipads or tablets
Vocabulary	repercussion: an unintended consequence occurring some time after an event or action, especially an unwelcome one (i.e. impacts)
Student Learning Outcomes	• Students will be able to explain several repercussions of climate change where they live using the National Climate Assessment, among other resources. • Students will be able to explain what makes a good scientific resource.
Performance Expectation(s) addressed	**MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Become familiar with the National Climate Assessment site before introducing it to your students. • Make copies of the Climate Change Repercussions Research Project worksheet for each student. • Make 1 sign for each of the Ten Indicators of A Warming World graphic and post around the room.

Background Information

Lesson 2 showed students that scientists are highly confident that many of these observed changes can be linked to the climbing levels of carbon dioxide and other greenhouse gases in our atmosphere, which are caused by human activities.

The National Climate Assessment (NCA) is an informational resource describing the impacts of climate change. It is a report that summarizes the impacts of climate change for the United States, now and in the future. Hundreds of experts, guided by members of the Federal Advisory Committee, produced the report, which was extensively reviewed by the public and experts, including the National Academy of Sciences. The report was turned into a website that will be used extensively in this lesson and in Lesson 5.

For educators that would like suggestions about how to use the National Climate Assessment in the classroom, visit this site: https://www.climate.gov/teaching/2014-national-climate-assessment-resources-educators. This site features a list of all key messages and guiding questions for every region in the US as well as links to other resources outside of the NCA.

In Lesson 2, students explored the many factors that are causing global temperatures to rise. Population increase, more agriculture activity, and the production of cement are just a few pieces of the puzzle. With all of these factors causing global temperatures to rise, it is just a matter of time before we start seeing the repercussions of those actions, indeed some of the repercussions are already being felt around the world.

Lesson 3: What are the repercussions of the rise in global temperature?

Rising temperatures are seen around the world

> *Climate change is already beginning to transform life on Earth. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. If we don't act now, climate change will rapidly alter the lands and waters we all depend upon for survival, leaving our children and grandchildren with a very different world.*
>
> *- Nature Conservancy*

There are several important repercussions (impacts) of climate change that can be stressed when discussing with students. Some impacts include:

1. Sea level rise. Already we are seeing people displaced by sea level rise, and there is strong potential of many more climate change refugees. This also takes away farmland.
2. Spread of diseases. Diseases (like malaria and west nile virus) that are spread by insects are expanding their range due to warmer weather.
3. Extreme weather events. Warmer ocean waters leads to more intense hurricanes. Warmer air holds more moisture, so heavy rainfall and floods are occurring around the world. Also extreme droughts are being seen during the dry season.
4. Ocean acidification occurs as carbon dioxide is absorbed by the ocean. This changes the pH, making it more acidic. This is killing coral reefs, which has huge effects on the species that depend on coral to live in.

In this lesson students will be doing a research project that will show many other repercussions of climate change. As part of this research project, students will need to find quality content from good, reliable sources. How can you be sure that the resource you are using is reliable? There are several clues that can help answer that question. It's a Googlized world, anyone can find a wealth of information on just about any topic. The challenge comes in selecting appropriate and reliable sources. Given that all sources are not created equal, learning to analyze and evaluate critically is an important part of the research process. Here are some criteria for analysis:

When students are looking at websites for resources have them ask these questions about the site:

1. Who is the author?
2. What are their credentials?
3. Who is publishing the information? Where does that organization get their funding? Why does it matter where they get their funding from? What does it mean if it is difficult or impossible to answer these questions? (Usually, when it comes to climate change publications, if these questions are not easy to answer from the first glance at the front page of a website, it probably isn't a good source).
4. Why was the site created? To persuade (or profit)? To inform? To entertain? To self express? To sell a product?
5. Was the page recently published or updated?

Also, find out if the article or research has been peer-reviewed, meaning have other scientists in the field reviewed the article to eliminate any errors and confirm the validity? This will further confirm that the information can be trusted and is a good resource.

Students may argue that the graphs in Lesson 2 were given by the teacher and students were not able to choose their own data. In this lesson, students will have the opportunity to find more evidence on their own. They also will learn what makes good evidence and how to look for credible sources.

Journal Activity

Students will create a table in their notebook that includes the ten indicators of a warming world and answers to three questions. During the presentations, students will write about each of their classmate's presentations: one question they have, one thing they learned, and one thing want to share with others. For the conclusion activity, students will create a concept map or detailed drawing about what they learned about climate change repercussions.

Activity Description

Introduction:

1. To introduce this activity, show students the Ten Indicators of a Warming World graphic. Post the ten indicators on signs around the classroom. Have students create a table in their notebook that includes the indicators and these three questions.
Give students time to walk around the classroom and answer the questions about each indicator.
2. Have a discussion about each of the Ten Indicators of a Warming World. Are there more indicators than just these? Have you seen any of these in your city/state?

Activity: National Climate Assessment Report and Research Project

1. Introduce the National Climate Assessment (NCA) to your class. This is the main resource they will be using to complete this activity. If possible, bring up the website and give the students a tour so they are familiar with the site. The website is also very navigable on the mobile devices if your students have access.

Indicator	What evidence about this indicator have you seen or read about?	What could be the impact of this indicator on wildlife, cities,etc.?	How is this indicator impacting you?
Ex. Increased Humidity			
fill in the blank			

a. The full Report is divided up into four different sections: Our Changing Climate (how and why the climate is changing), Sectors (how climate change is affecting various sectors), Regions (how climate change is affecting specific regions of the US), and Response Strategies (exploring actions to reduce greenhouse gas emissions and adapt to climate change).
b. The NCA summarizes the impacts of climate change on the United States, now and in the future. Explain that this website was produced by more than 300 experts and has been extensively reviewed by the public, experts, and scientists in many fields.
c.Show your students that there is also a Highlights section (divided into 3 parts: Overview, Report Findings, and Regions. The site also has pictures and graphs that explain the repercussions of climate change in a simple yet exciting way.

2. Before you let students start on this activity, have a discussion about how to find good resources and how to check if your resource is valid. What qualifies as a good resource? Consult the background information for this lesson for help leading this discussion.
3. The National Climate Assessment (NCA) Scavenger Hunt activity will help students become familiar with the National Climate Assessment website. If you have time the activity is included with this lesson.
4. Pass out the Climate Change Repercussions Research Project worksheet. Remind students that they need to stay on this website for their research. Students will be researching a particular region or sector and finding graphs and figures that support the message about how climate change is affecting that area. The worksheet for this activity can be found on page 58.

a. Student Directions: We know that the climate is changing. And we know that humans are contributing to those changes. This activity will help you become familiar with the repercussions that the area you live in may be experiencing now or in the future. Follow the directions closely so you get to the right spot. Write the answers to the following questions in complete sentences. Go to the National Climate Assessment website: http://nca2014.globalchange.gov/. Click on 'Explore the Report.' Find the region where you live (i.e. Midwest, Southwest, etc.) or choose a Sector that interests you. Search for repercussions on climate change in your area by reading the Key Messages for that Region or Sector. After choosing a Key Message to focus on, you will be asked to find 3-4 graphs or figures that support that key message.
b. You can choose if you want students to use the Report or the Highlights section. The Report would be better for advanced classes or upper grade levels.
c. Students will prepare a speech about their Key Message and information they found about their Region or Sector's Key Message. These can be presented to the class or just turned in as a written paper.

Conclusion Activity

In student journals, ask them to make a graphic about what they learned about the repercussions of climate change in their area. This could be a concept map (climate change could be in the middle with different repercussions branching off of that. Student could further explain the repercussions as well.) Or students could make a Venn Diagram (list two repercussions and compare them) or a detailed drawing showing pictures of various repercussions. Being outside for this activity will help students see connections to the natural world and the changing climate.

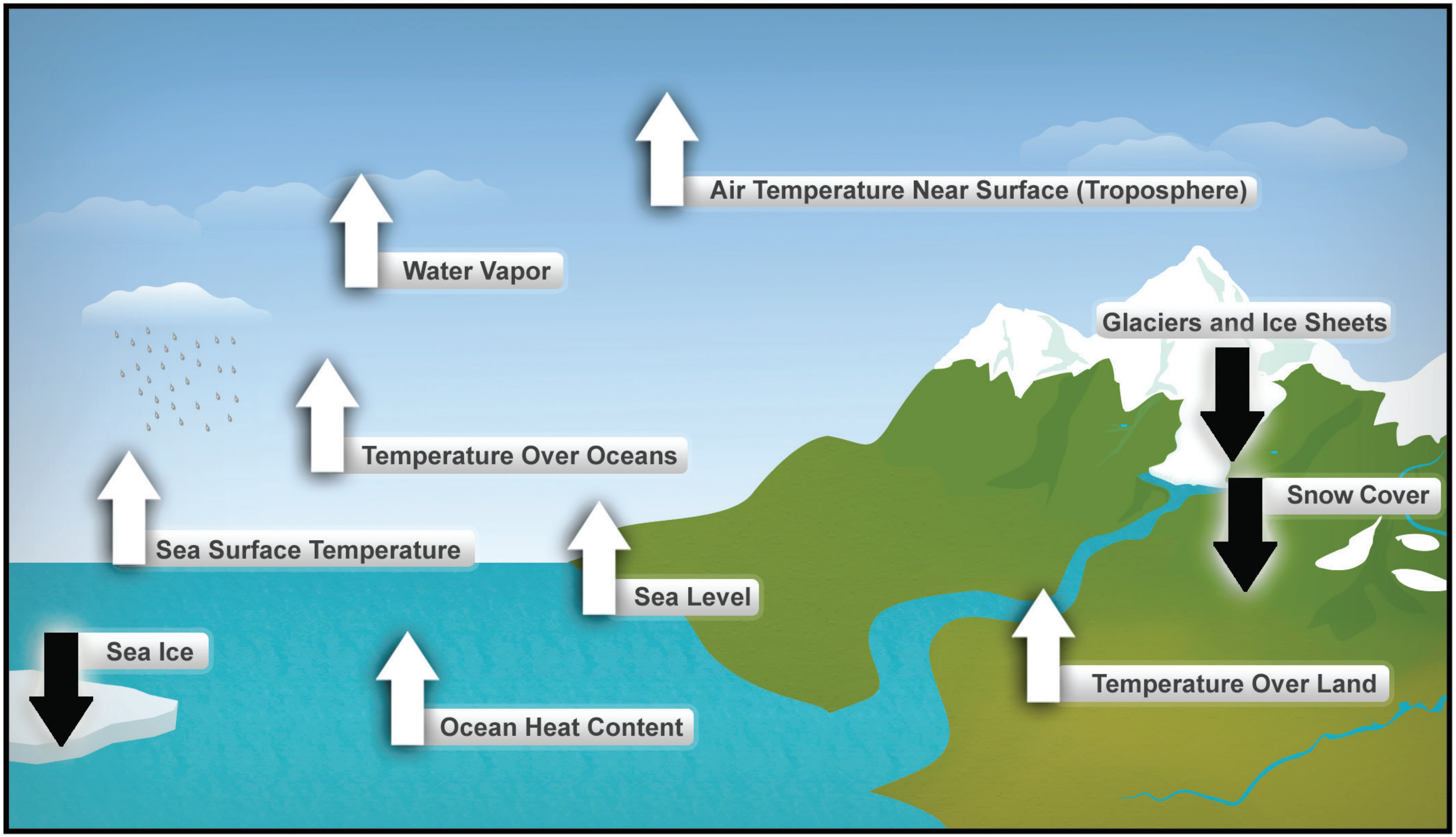
Extensions

1. The NCA Scavenger Hunt on page 58 will help students understand the magnitude of the National Climate Assessment website. The NCA Scavenger Hunt was designed to help students navigate the site and therefore be able to easily find information when doing their research project. The Scavenger Hunt can be omitted if you do not have time, but will be beneficial for the students to navigate the National Climate Assessment report online. It could also be completed in groups to speed things up.
2. Here are three extensions for the Climate Change Repercussions Research Project:
    a. Continue using NCA to do another research project, but this time use another region or go more in depth with this research project.
    b. Have students find one supporting figure or resource to their Key Message that's not from the NCA site. Examples of outside figures can be found for each region's key messages at http://www.climate.gov/teaching/2014-national-climate-assessment-resources-educators
    c. Using two reliable science websites, find two articles that address this change (Key Message) in your area. If you can't find one for your area, broaden your search to another part of the US. Examples of outside websites can be found for each region's key messages at http://www.climate.gov/teaching/2014-national-climate-assessment-resources-educators

Resources

National Climate Assessment Regional Support Pages: http://www.climate.gov/teaching/2014-national-climate-assessment-resources-educators. For additional assistance with website relieability: https://owl.english.purdue.edu/owl/resource/588/02/

Ten Indicators of a Warming World



National Climate Assessment and Development Advisory Committee. (2010). Ten Indicators of a Warming World.
Retrieved from http://www.globalchange.gov/browse/multimedia/ten-indicators-warming-world
(Figure source: NOAA NCDC based on data updated from Kennedy et al. 2010)

Name ______________________________

Student Worksheet: National Climate Assessment Scavenger Hunt

Directions: Navigate your browser to the National Climate Assessment found at: nca2014.globalchange.gov. Answer the following questions by navigating the site, exploring the different sections, and utilizing the various features.

1. Who produced the National Climate Assessment Report?

2. Where can you find a brief highlighted version of the report details about the section *Our Changing Climate*?

3. Within the *Our Changing Climate* page, interact with the Arctic Sea Ice Decline graphic and explain the difference between the 1984 and 2012 pictures.

4. Download the Screen version of the Water Sector.

5. From question three, how do you return to the home page?

6. How many Convening Lead Authors, Lead Authors, and Contributing Authors are there for the Northeast Region's report?

7. How many Key Messages are there for the Northwest Region and what are they?

8. Where would you find the section on Human Health? Start this search from where you were at the end of question 6.

9. Looking at Key Message 3 in the Human Health Sector, what is listed as the Assessment of confidence based on evidence?

10. In the Agriculture sector, find the original source (website) from footnote 203's citation.

11. What is the title of Figure 2.16?

12. What is the projected change in tick habitat in the United States by 2080?

13. You feel like Figure 25.1 is very valuable and you want to share it with friends; how would you do that?

14. Download the Climate Science Supplement or FAQS.

15. How many Response Strategies are listed in the Climate Assessment Report and what are they?

16. According to the Research Needs section, how many research goals are there?

17. Return to the *Our Changing Climate* section. How many key messages does this chapter present? What is the sixth message?

18. There are so many resources that were used to write this assessment. Who is the author of *Hawaiian Natural History, Ecology, and Evolution*?

19. According to the Water Sector, what are the trends in flood magnitude for the Midwest and southwest?

20. What are the key messages about rural communities?

NCA Scavenger Hunt Answer Key for Teacher

1. Find who produced the National Climate Assessment Report.

> **Answer:** A team of more than 300 experts guided by 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences. (Found at the bottom of every page of the report.)

2. Where can you find a brief highlighted version of the report details about the section *Our Changing Climate*?

> **Answer:** By clicking Explore Highlights, select report findings, select Explore Report Findings, and last click on *Our Changing Climate.*

3. Within the Our Changing Climate page, interact with the Arctic Sea Ice Decline graphic and explain the difference between the 1984 and 2012 pictures.

> **Answer:** In 1984 there was a lot more ice. The ice reached across the entire Arctic Sea. By 2012, the ice had lost about half its area. Found by scrolling down the Our Changing Climate page and interacting with the above mentioned graphic.

4. Download the Screen version of the Water Sector.

> **Answer:** On any page in the top right corner, click on 'download'. Then find the category called 'sectors' and select Water. The Screen download version is the first column and Print is the second column

5. From question three, how do you return to the home page?

> **Answer:** Click the globe in the top left corner

6. How many Convening Lead Authors, Lead Authors, and Contributing Authors are there for the Northeast Region's report?

> **Answer:** Nine. Found by selecting Explore the Report, select Regions, then Explore Regions, Select Northeast, and then select the three author categories above the Introduction. OR from the main screen select the three horizontal bars in the top left corner, then select Regions, and Northeast (for highlighted version).

7. How many Key Messages are there for the Northwest Region and what are they?

> **Answer:** There are 4 main Key Messages- Water Related Challenges, Coastal Vulnerabilities, Impacts on Forests, and Adapting Agriculture. Found by selecting the Northwest region and scrolling down or selecting 1,2,3, or 4 at the top of the screen.

8. Where would you find the section on Human Health? Start this search from where you were at the end of question 6.

> **Answer:** Select the three horizontal bars in the top left corner, select Sectors, then Human Health.

9. Looking at Key Message 3 in the Human Health Sector, what is listed as the Assessment of confidence based on evidence?

> **Answer:** High. Found by scrolling to Key Message 3 under Human Health and selecting Supporting Evidence, scroll to the bolded section called Assessment of Confidence Based on Evidence.

10. In the Agriculture sector, find the original source (website) from footnote 203's citation.

> **Answer:** Within the Agriculture Sector find citation 203 under food Security, click the blue number, then Click the URL link and it will take you to the original source.

11. What is the title of Figure 2.16?

Answer: Observed U.S. Trend in Heavy Precipitation. Found by typing in 2.16 in the search bar in the top right corner, then select graphics.

12. What is the projected change in tick habitat in the United States by 2080?

Answer: There is an overall increase in tick establishment in the Midwest and East Coast. Found by typing tick into the search bar, selecting Figure 9.5, Projected Changes in Tick Habitat, and then using the interactive graphic.

13. You feel like Figure 25.1 is very valuable and you want to share it with friends; how would you do that?

Answer: Select the bird icon for Twitter and "f" for Facebook, then Share link.

14. Download the Climate Science Supplement or FAQS.

Answer: Select the three horizontal bars in the top left corner, make sure Report is selected and not Highlights, at the bottom of the box is Climate Science Supplement and FAQS, select either to download.

15. How many Response Strategies are listed in the Climate Assessment Report and what are they?

Answer: There are five response strategies: decision support, mitigation, adaptation, research needs, and sustained assessment. Found by select the three horizontal bars in the top left corner, make sure 'Report' is selected. Select Response Strategies and the categories will be listed underneath.

16. According to the Research Needs section, how many research goals are there?

Answer: There are 5 research goals. Found by clicking on the three horizontal bars in the top left corner, select Report, Response, Strategies, and finally Research Needs. Scroll through the page to see the goals.

17. Return to the Our Changing Climate section. How many key messages does this chapter present? What is the sixth message?

Answer: There are 12 key messages. Select the three horizontal bars in the top left corner, select report, and then Our Changing Climate. Click on 'Introduction' for the number of sections, then return to the last page to find the 6th message.

18. There are so many resources that were used to write this assessment. Who is the author of Hawaiian Natural History, Ecology, and Evolution?

Answer: Ziegler, A.C. Found by typing 'Hawaiian Natural History' into the search bar in the top right corner.

19. According to the Water Sector, what are the trends in flood magnitude for the Midwest and southwest?

Answer: The Midwest flood magnitude trend is positive (3-18%) and the Southwest flood magnitude trend is negative (3-18%). Found by selecting the three horizontal bars in the top left corner, then select sectors, and select water. Scroll down page to key message three and click on Figure 3.5: Trends in Flood Magnitude. Or type 'trends in flood magnitude' into the search bar in the top right corner. Scroll down and select figure 2.21.

20. What are the key messages about rural communities?

Answer: Rural economics, responding to risks, adaptation. Found by selecting the three horizontal bars in the top left corner, select highlights, and then select regions. Click on Rural Communities and scroll through the page to see the key messages.

Name ______________________________

Student Worksheet: Climate Change Repercussions Research Project

Directions: We know that the climate is changing. And we know that humans are contributing to those changes. This activity will help you become familiar with the repercussions (impacts) that the area you live in may be experiencing now or in the future. Follow the directions closely. Write the answers to the following questions in complete sentences.

1. Go to the National Climate Assessment website: http://nca2014.globalchange.gov/. Click on 'Explore the Report.' Find the Region where you live (i.e. midwest, southwest, etc.) or choose a Sector that interests you. Search for repercussions on climate change in your area by reading the key messages for that region or sector. Write down the key message that interests you the most.
Region or Sector:

Key Message:

2. After choosing a Key Message to focus on, you will find 3-4 figures that support that key message. Write down the name of the figure below and explain why it supports your key message. You may need to use the search bar to find additional figures.

a. Figure: ________________________
Why does it support the key message?

b. Figure: ________________________
Why does it support the key message?

c. Figure: ________________________
Why does it support the key message?

d. Figure: ________________________
Why does it support the key message?

3. Thinking back to the earlier figures you looked at regarding the rise in global temperature and using your own creativity, what is one way this key message could be addressed?

4. It is important to choose graphs and information that are reliable. How do you know the graphs and figures you chose are reliable? Where did your figure come from and how do you know it's reliable?

5. Prepare a short speech, video, slide show, etc. (2-3 minutes) to share with the class. Your speech should include your key message (and what region/sector it is from), a short discussion of the graphs/figures you chose, and two things that could be done to reduce the impact of this problem.

Age Level	Grades 6-8
Time Needed	Two 50 minute class periods
Materials	Scientists in Action worksheet (1 for each student) Scientist Stories (1 classroom set) Citizen Science slideshow Citizen Science equipment (if needed)
Vocabulary	**citizen science:** Public volunteers of all ages assisting scientists in their research **resilience:** Capacity to recover quickly from difficulties, toughness (Resilience comes from having the capacity to respond to change.)
Student Learning Outcomes	• Students will be able to describe how scientists are monitoring the repercussions of climate change. • Students will be able to explain what citizen science is and be able to participate in a citizen science project.
Performace Expectation(s) addressed	**MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Make copies of the Scientists in Action worksheet for each student. • Make a classroom set of the Scientist Stories. Make 6 'scientist stations' around the classroom. Students will visit each station to learn about the scientist and answer questions on their worksheet. • Before doing the Citizen Science Activity, familiarize yourself with several citizen science examples. Choose one that you could participate in with your students, or let your students decide which one they would like to participate in. Sign up before the start of the lesson and, if possible, obtain the necessary tools to allow your students to begin collecting information right away.

Background Information

At this point students have learned that there is an ongoing rise of the global temperature and about the repercussions that are happening because of that rise. In this lesson, students will learn how scientists monitor the repercussions of climate change and how they can also participate in monitoring.

It is important to monitor the repercussions of climate change, because only if we know the impacts will we able to plan for the future and develop methods to minimize them. For example, monitoring the population of certain trees is crucial because their health impacts many species including other trees, insects, and animals. In Minnesota, aspen and tamarack trees are dying from changes in precipitation patterns, temperature fluctuations, and insect defoliation. Being able to monitor these changes is crucial to understanding what needs to be done to help save these species.

Emphasize to students that in order to monitor these repercussions, it takes time. Point out that while monitoring, scientists are looking for trends. As we discussed in earlier lessons, long term trends cannot be determined from just a few years, more time is needed to fully understand what and how things are happening in nature.

Journal Activity

Students will use their journals to collect a definition of citizen science, list projects they would like to work on (including pros and cons to those projects), and collect information for a class citizen science project. Students will answer questions about scientists involved in climate change research.

Activity Description

Introduction:

Class discussion

1. Use this introduction to review the repercussions of climate change. Have students share the key messages from the National Climate Assessment that they collected from Lesson 3. You could bring back some of the figures from Lesson 1 or 2 and discuss the repercussions they show.
2. Ask students to refer back in their journals to the Temperature Indicators worksheet in Lesson 1. Show some of the figures that they saw and ask students to comment on how they determined the data had been collected and who/what organization had been the one to collect it.

Activity 1: Scientists in Action

1. In this activity students will learn about scientists that are working on issues related to climate change. Students will read about the ways in which these scientists are engaging in actively monitoring the repercussions of a changing climate. Introduce the scientists and what they study to your students:

   a. Rupa Basu: Public Health and Heat
   b. Charles David Keeling: Atmospheric carbon dioxide levels
   c. Rebecca Montgomery: Forest Ecology
   d. Karen Oberhauser: Butterflies
   e. Tracy Twine: Changes in our atmosphere
   f. Jim White: Ice Cores

2. Make six stations around your classroom with a Scientist Story at each station. Break students into small groups of 4-5 students. Assign each group to a station to start.
3. Pass out the Student Worksheet: Scientists in Action. Before looking at the Scientist Stories, ask students to write a hypothesis about how the scientist is monitoring the repercussions of climate change, just based on the topic of study and what they already know about how data is collected.
4. In their groups, students will take turns reading the Scientist Story at their station. Each story includes background information on the scientist, where they work, and what kind of research they are doing. Students will answer the following questions on their worksheet:

   a. Write a hypothesis about the work this scientist is doing.
   b. What schools did this scientist attend?
   c. What degrees does this scientist hold?
   d. What is this scientist's job title?
   e. How is this scientist monitoring the repercussions of climate change?
   f. What tools does this scientist use to monitor the environment?
   g. Is this scientist also minimizing climate change? How?

> *Humans continue to change the environment locally, regionally and globally. We have eliminated and introduced species, changed resource availability, fragmented the landscape and altered climate. Understanding the response of natural systems to these changes requires knowledge of the mechanisms through which organisms respond to the...environment.*
>
> *- Rebecca Montgomery*

5) After reading about all of the scientists who are monitoring climate change, students will answer the conclusion questions at the bottom of the worksheet.

Activity 2: Citizen Science

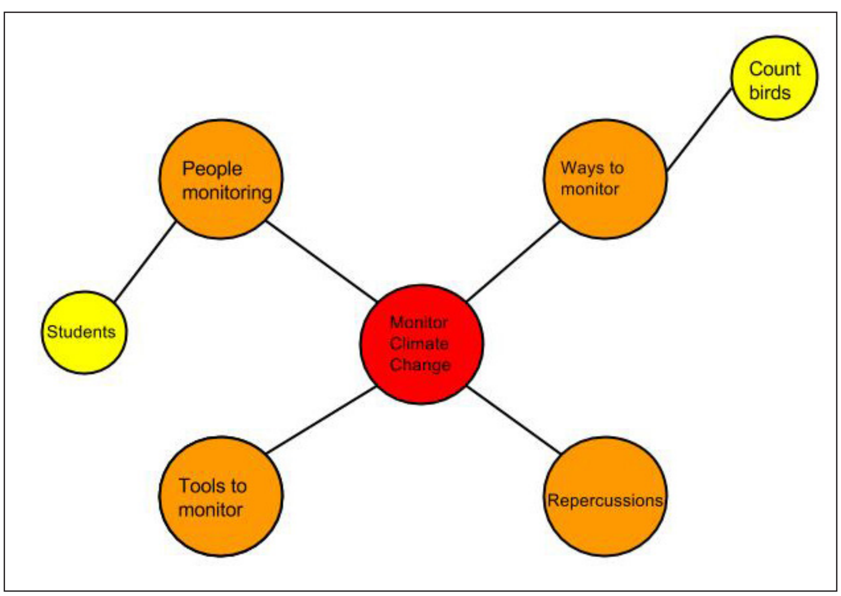
1. Ask students if they have heard of citizen science. If so, what are they interested in? Use the Citizen Science slideshow on pages 80 and 81 (or download from the Climate Generation website www.climategen.org/ngconline) to introduce students to citizen science and give examples of citizen science projects. Have them take notes about what citizen science is and projects they are interested in.
2. With a partner, ask students to write down two projects they would be interested in. For each one they should also write two pros and two cons, what information they should find while participating, and how this project will help monitor the repercussions of climate change.
3. Have students vote for the project they would like to contribute to, or you can choose which one would be easiest, most beneficial to the students, or fit in best with other lessons.
4. Depending on the project(s) that you choose to do, have students create a plan in their journals to execute the project.

Take it Outside

Students will participate in a citizen science project with their classmates. Students will use their science notebooks to collect information outside on a daily, weekly, or monthly basis (depending on the nature of the project and the amount of involvement the teacher would like to have).

Conclusion

Have students share the information they have collected. An easy way to do this is to make a Concept Map as a class. Here is the start of an example:



Extensions

1. Have various groups of students choose different citizen science projects to contribute to. They can collect for a few months and then present their data to the class.
2. Instead of presenting the Citizen Science slideshow to students, split them into groups and have them research one of the citizen science sites featured in the slide show. They could collect information and present to the class: equipment needed, time needed each week, length of project, what they will record, etc.
3. Ask students to use data that they have collected to create their own figures that show trends or variations in climate or repercussions of climate. Exchange figures between students for "peer review" and clarifying questions.
4. Download citizen science data from CoCoRaHs, the Globe Program, Project Budburst or the National Phenology Network (see resources for links) and ask students to use the data to create their own figures that show trends or variations in climate or repercussions of climate. Exchange figures between students for "peer review" and clarifying questions.

Resources

1. Climate Change and Citizen Science (slideshare). http://www.slideshare.net/CitizenScienceCentral/citizen-science-and-climate-change-west
2. CoCoRaHS: Community Collaborative Rain Hail and Snow Network http://www.cocorahs.org/
3. The Globe Program https://www.globe.gov/globe-data
4. Project Budburst http://budburst.org/results_data
5. The National Phenology Network https://www.usanpn.org/#

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Name ______________________________

Student Worksheet: Scientists in Action

Directions: First, make a hypothesis as a group about how you think each scientist is monitoring the repercussions of climate change. Second, read the information about the scientist and answer the questions together in your journal. Be as specific and detailed as you can. Third, answer the conclusion questions at the end of the worksheet (attach an extra sheet with answers).

Scientist 1

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Scientist 2

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Scientist 3

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Scientist 4

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Scientist 5

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Scientist 6

Write a hypothesis about the work this scientist is doing

What schools did this scientist attend?

What degrees does this scientist hold?

What is this scientist's job title?

How is this scientist monitoring the repercussions of climate change?

What tools does this scientist use to monitor the environment?

Is this scientist also minimizing climate change? How?

Conclusion Questions

1. How are these scientists connected? (pick two and compare)

2. How does their work influence each other? (pick two and explain)

3. How is their work connected to you? (pick two and show connection)

4. Could you participate in any of their projects, or anything similar?

5. What are other ways you could monitor the repercussions of climate change?

6. On your own, pick one of your ideas from #5. Write 5 sentences about what and how you could monitor the repercussions of climate change.

Rupa Basu, PhD, MPH

Rupa Basu is studying the health effects that heat can have on humans. She is Chief of the Air and Climate Epidemiology Section and works as an epidemiologist at California Environmental Protection Agency's Office of Environmental Health Hazard Assessment. She has two boys and is concerned about the changing world they will be inheriting. At home, Rupa has taught her boys the importance of recycling and composting. She bikes to work whenever possible and purchased an electric car to eliminate the carbon pollution when she has to drive.

She received her Bachelor of Science degree in Biology from the University of California, San Diego, a Master of Public Health from the University of California, Los Angeles, and a Ph.D. from the Johns Hopkins University in Epidemiology (Environmental and Occupational). Her education and research interests have lead her to explore the health outcomes associated with the warm season in California, and investigate which populations are most at risk during these warm months.

In a research study that was published in the American Journal of Epidemiology, Basu and colleagues analyzed the association between high temperatures and preterm delivery. They looked at weather data and birth certificates in California to conduct their study. They found that high ambient temperature was significantly associated with preterm birth for all mothers, particularly African-Americans, Asians, and younger mothers. Other health outcomes that have been studied by the same research team include specific diseases and populations at risk for deaths, hospital visits, and emergency room visits that are related to high temperature. As the global temperature is projected to rise, heat-related health concerns will become an issue for many people all around the world.

In an episode of "Years of Living Dangerously," Rupa discussed those most at risk of heat related deaths and the large numbers of people that are dying. The elderly, infants, and young athletes that practice outside are groups that are at a high risk. In the California heatwave of 2006, about 140 deaths were attributed to heat according to coroner's' reports, but she admits that number is actually up to three to four times higher. Heatwaves are going to be more frequent in the future and last longer. "In raising our children we definitely think about climate change. The temperature is definitely changing everywhere. A lot of people are dying because of heat waves. This is something we are seeing worldwide."

Charles David Keeling

Charles David Keeling created an icon of modern climate science. The "Keeling Curve" has become a standard icon symbolizing the impact of humans on the planet. As a professor of oceanography for Scripps Institution of Oceanography at the University of California, Keeling was able to observe and monitor the rise in human-induced carbon dioxide.

Keeling earned a Bachelor of Arts degree in general Liberal Arts from the University of Illinois in 1948. In 1954, he continued his education by earning a Ph.D. in Chemistry from Northwestern University. Keeling began his career as a postdoctoral fellow at the California Institute of Technology. He wanted to study carbon dioxide (CO_2) levels in the atmosphere. Because Keeling was the first person to measure CO_2 levels, there was no instrument he could use. So he did what any good scientist would do, he created the instrument himself.

By 1958, Keeling began an extensive survey of the atmospheric carbon dioxide concentration in the air. One location of survey data was collected from Mauna Loa Observatory in Hawaii. He installed his carbon dioxide instrument on the side of a weather station on the summit of an extinct volcano. Measurements from this location changed the notion of the atmospheric CO_2 increase from fiction to fact, and are still being taken today.

Another discovery that Keeling made, within a year of being on Mauna Loa, was the cycle that carbon dioxide made throughout the year. In the summer, the CO_2 levels decreased because plants needed it for photosynthesis. In the winter, when the leaves fell off the trees, the CO_2 levels increased. Over the years, this has shown scientists that spring has been arriving one week earlier than it did in the 1960s.

Thomas Barton, Ph.D., past president of the American Chemical Society had this to say about Keeling, "Dave Keeling's meticulous research provided scientifically credible evidence that has proved critical to understanding and addressing human impacts on our environment." Carbon dioxide measurements are still being taken at Mauna Loa and are made public everyday on the Keeling Curve website and Twitter feed.

Rebecca Montgomery

Rebecca Montgomery studies and teaches about forest ecology. She is a professor in the Department of Forest Resources at the University of Minnesota. She teaches Forest Ecology classes and participates in many research projects through the University of Minnesota and Cedar Creek Ecosystem Science Reserve.

Rebecca received her Bachelor's degree from Occidental College in Biology and earned her Ph.D. from the University of Connecticut in Ecology. Her education has lead her to study how humans are changing the environment around us.

"Humans continue to change the environment locally, regionally and globally. We have eliminated and introduced species, changed resource availability, fragmented the landscape and altered climate. Understanding the response of natural systems to these changes requires knowledge of the mechanisms through which organisms respond to the abiotic and biotic environment." Research in her lab focuses on understanding these mechanisms and helps to understand important topics such as: the effects of global climate change on land ecosystems and how exotic species invade new habitats.

Rebecca is involved in several research projects with her students at the University of Minnesota. Much of her research is related to climate change and what the repercussions look like. One such study is looking at the potential for projected climate change to change the composition of the tree species between the southern boreal forest and the temperate forest. With a warming climate, certain tree species will die off because the temperatures will be too warm for them to survive.

Another project that Rebecca is working on, BioCon, is taking place at Cedar Creek Ecosystem Science Reserve. The goal of BioCON (biodiversity, CO_2, and Nitrogen) is to explore the ways that plant communities will respond to environmental changes that are already happening across the globe (increasing nitrogen deposition, increasing atmospheric CO_2, and decreasing biodiversity).

Karen Oberhauser

Karen Oberhauser loves butterflies. She studies them, teaches about them, and is helping to bring back their population. She is a Professor in the Fisheries, Wildlife, and Conservation Biology Department of the University of Minnesota. She also participates in many eco-friendly practices at home: relandscaping with native plants in her yard, walking or biking to work, and installing a geothermal heating and cooling system for her house.

She received a Bachelor's degree in Biology from Harvard College and her Ph.D. from the University of Minnesota's Department of Ecology in Evolution and Behavior. Her education has lead her to study monarch butterflies. "I conduct research and teach in the fields of conservation biology, insect ecology, global climate change, and monarch butterfly population dynamics."

Oberhauser is involved in several research projects with her students and the government. In 1996, she and graduate student Michelle Prysby started a nationwide Citizen Science project called the Monarch Larva Monitoring Project. This project helps understand monarch egg and larval distribution in monarch breeding grounds throughout North America. Participants in the program use butterfly nets and hand lenses to find eggs and larva. They also use field guides for reference, rain gauges to track precipitation in the area, and the internet to report their data each week. Citizens can also participate in Monarch tagging so scientists like Oberhauser can better understand monarch migration patterns.

Karen is also doing specific research about how monarchs will be affected by climate change. A paper published in 2012, "Tracking climate impacts on the migratory monarch butterfly," suggests that understanding the effect of our changing climate on monarchs will be challenging. But through more training of teachers, naturalists, and students, more data will be collected and plans can be made to save the monarchs.

Another project that Karen is involved in started Fall 2015. Milkweed plants will populate backyards and roadsides from Duluth to Texas.The current use of pesticides, like Roundup has decimated the milkweed in the prairies of the Midwest. The introduction of more milkweed plants will help increase monarch numbers as milkweed is the only food source for monarch caterpillars. "We are going to get the most bang for our buck by concentrating on the prairie corridor," said Karen Oberhauser, a University of Minnesota professor and one of two key scientists advising federal agencies on the monarch plan.

Tracy Twine

Tracy Twine enjoys learning about the atmosphere. She studies it, teachers about it, and is helping to understand it in order to predict how it might change in the future. She is a Professor in the Department of Soil, Water, & Climate at the University of Minnesota. Tracy also is very conscious of her impact on the earth in her personal life: she walks to work, her family only has one car and it's a hybrid, and she limits her airplane flights and purchases carbon offsets when she must fly.

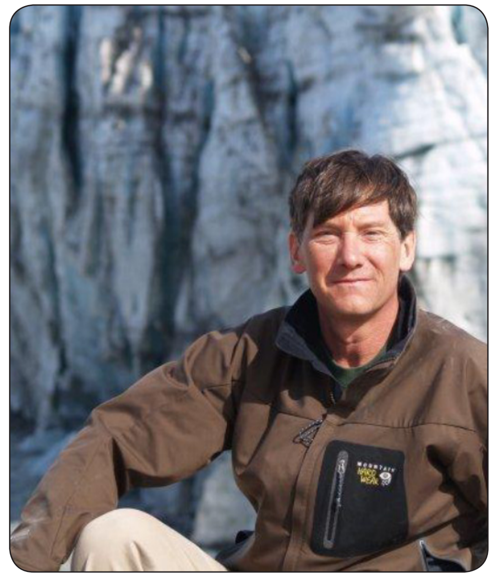
She received her undergraduate degree in meteorology from Pennsylvania State University. Her advanced degrees include a Master's of Science and Ph.D., both in Atmospheric and Oceanic Sciences both from University of Wisconsin Madison. Her education has lead her to study how human land use and climate change affect the structure and functioning of natural and managed ecosystems. "I am most interested in the part of the atmosphere in which we live—right at Earth's surface. The exchanges of energy, carbon, and water are important for the welfare of ecosystems, yet their complexities make them difficult to quantify, and even more difficult to predict how they might change in the future."

Tracy is involved in several research projects in her lab at the University of Minnesota. They all relate to climate change in some way, and how the changing atmosphere is playing a role. Three of her projects are: Climate Change and Agroecosystems (working to understand how climate change will affect farming), Future Food Security (predicting how maize and wheat yields may change in the future), and Effects of Land Cover Change for Biofuel Production (managing biofuel crops in a sustainable way).

Tracy was recently featured in a television production with Climate Generation about her work with urban heat islands. She and her colleagues are examining the characteristics of 100 urban heat islands and collecting air temperature every 15 minutes in Minneapolis and St. Paul to compare. They are using a network of 200 sensors placed in residential backyards around the Twin Cities Metro Area to record these temperatures. Tracy's team hopes to help protect human health and avoid excess energy consumption with their findings.

Jim White

Jim White is an ice core expert. By studying ice cores (large pieces of ice that have been drilled out of glaciers) he can find out how much greenhouse gases (methane, co2) were in the atmosphere years ago. Jim is a professor of Geological Sciences at University of Colorado Boulder. He is also a Fellow and Director at the Institute of Arctic and Alpine Research.



He earned a Bachelor's of Science degree in Chemistry from Florida State University and his Ph.D. from Columbia University in Geochemistry. His education has led him to study carbon dioxide, methane and other gases from prehistoric atmospheres in order to understand how the levels of atmospheric gases has changed in the past.

Jim is able to study the atmospheres of the past by analyzing what is trapped in the ice cores. "One of the things you can easily see in this ice core are small bubbles. And that's the atmosphere trapped at the time that this particular ice was formed." Jim and his team are able to record how much greenhouse gas was in the atmosphere when the ice and snow fell. This information is important for figuring out how climate change could affect the world in the future. "The past gives us some clues about what could occur in the future."

Jim gets ice core samples sent from Greenland and Antarctica to his lab in Boulder, CO. These ice core samples are retrieved by drilling through ice and bringing up pieces that are 4-6 meters in length. Cores are bagged up to protect them from contamination and always kept very cold. Scientists need to work on the cores with gloves on so they don't melt. Ice cores are stored in large freezers so scientists can work on them later. Jim's team will take measurements from about 10,000 samples each year.

Citizen Science

What can we do to contribute?

Why Citizen Science?

- Scientists are seeing changes around the world: on the land and in the oceans and air.
- To be certain those changes are related to climate change, scientists need observations from around the world for extended periods of time.

Why Citizen Science?

- Instead of working alone, some researchers and scientists will invite volunteers to help
- These are called Citizen Science Projects

What is Citizen Science?

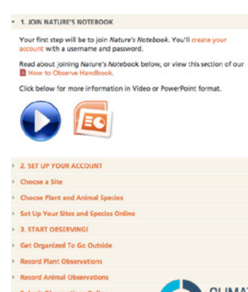
- Public volunteers assisting scientists in their research
- “Scientists can’t be everywhere, so kids from all over can record data and send it in.” Heidi, grade 7
- Citizen science is important! It’s a partnership between the public and professional scientists that can help answer questions scientists couldn’t answer on their own. Citizen science encompasses a broad range of topics, geographic settings, and strategies.
- It’s easy to participate

Project Budburst

- Mission Statement: "Engage people from all walks of life in ecological research by asking them to share their observations of changes in plants through the seasons."
- We are a national field campaign designed to engage the public in the collection of important ecological data based on the timing of leafing, flowering, and fruiting of plants
- Project BudBurst is open to people of all ages and abilities
- http://budburst.org/

Nature’s Notebook

- When you participate in the program, you’ll go outside to observe nature in your backyard or nearby area weekly and enter this information online.
- As part of Nature’s Notebook, you are invited to observe both plants and animals. Observing phenology is very similar for both, however, because animals move around and plants do not, there is one important difference in the way we ask you to observe the two groups.
- https://www.usanpn.org/nn/become-observer



Cornell Lab (birds)

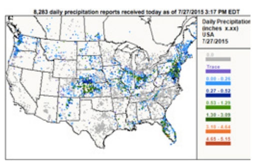
- **Project FeederWatch**: Help scientists track bird population movements and monitor long-term trends in the distribution and abundance of birds in winter.
- **NestWatch**: You'll keep track of what kinds of birds are using the nests, how many eggs were laid, and the number of chicks hatched.
- **Celebrate Urban Birds**: Look for 16 species of birds for 10 minutes anywhere, any time, and share your observations
- **YardMap**: innovative web tool you use to tell us about the habitat available to birds in your backyards, local parks, schools, and favorite birding spots
- **Great Backyard Bird Count**: Take part in this free, annual event that compiles bird counts from around the world to create a snapshot of bird populations in winter.
- **eBird**: a simple way to record your observations online and share what you've seen with scientists, educators, and other bird watchers
- http://www.birdsleuth.org/Citizen%20Science/

Cornell Bird Citizen Science Programs

	Project FeederWatch	NestWatch	Celebrate Urban Birds	YardMap	Great Backyard Bird Count	eBird
Focal Species	Birds at feeders	Any species	16 focal species	Any species	Any species	Any species
Season	November-April	Spring & Summer	Any season	Any season	Mid-February	Any season
Geographic Area	U.S. & Canada	U.S.	Worldwide	U.S. & Canada	Worldwide	Worldwide
Required Tools						
Key to Tools	Required Tools: Bird Feeder(s) Internet Binoculars					

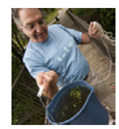
CoCoRaHS

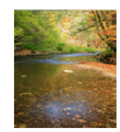
- CoCoRaHS: Community Collaborative Rain, Hail and Snow Network
- Volunteers of all ages and backgrounds working together to measure and map precipitation
- Each time a rain, hail or snow storm occurs, volunteers take measurements of precipitation from as many locations as possible
- Only requirements to join are an enthusiasm for watching and reporting weather conditions and a desire to learn more about how weather can affect and impact our lives.
- http://www.cocorahs.org/

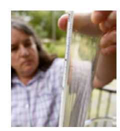


Citizen Stream-Monitoring

- The Citizen Stream-Monitoring Program (CSMP) combines the knowledge and commitment of interested citizens with the technical expertise and resources of the Minnesota Pollution Control Agency (MPCA).
- Any person or group willing to devote a small amount of time and energy to conduct simple stream checks on a regular basis can become a volunteer monitor.
- Program Goal: Help determine the condition of Minnesota streams by expanding our water-quality monitoring network.
- http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/citizen-stream-monitoring-program/index.html





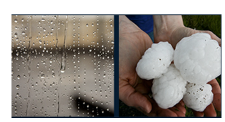


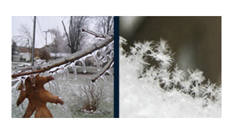
Citizen Lake Monitoring

- The CLMP is a cooperative program combining the technical resources of the Minnesota Pollution Control Agency (MPCA) and the volunteer efforts of citizens statewide who collect water-quality data on their lakes.
- Any person or group willing to devote a small amount of time and energy to conduct simple water-quality checks on a regular basis can become a volunteer monitor.
- The only restriction is that volunteers need to have access to a boat or canoe in order to take the transparency readings.
  - http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-water-monitoring/volunteer-duties.html

mPing

- The NOAA National Severe Storms Laboratory is collecting public weather reports through a free app available for smart phones or mobile devices.
- The app is called "mPING," for Meteorological Phenomena Identification Near the Ground.
- To use the app, reporters select the type of weather that is occurring, and tap "submit." The anonymous reports can be submitted as often as every minute.
- http://mping.nssl.noaa.gov/





GLOBE

- GLOBE is proud to partner and interact with a worldwide community of teachers, students, scientists and organizations from around the world through hands-on investigation and engagement with Earth.
- Once teachers have attended a GLOBE training event, they are provided with the knowledge and tools to implement GLOBE protocols and learning activities in a classroom setting
- https://www.globe.gov/join

Which one should we choose?

- With a partner, write down two projects that interest you
- For each one write the following:
  - two pros and two cons
  - what information you will find while participating
  - how this project will help monitor the repercussions of climate change
- Share your thoughts with the class
- Vote for the one that interests you the most

Age Level	Grades 6-8
Time Needed	Three 50 minute class periods
Materials	Impacts, Mitigation, Adaptation Prompt Lines (1 for class) Mitigation and Adaptation Venn Diagram Worksheet: Adaptation & Mitigation Scenarios (1 for each student) Worksheet: Claim, Evidence, Reasoning (Mitigation and Adaptation) (1 for each student)
Vocabulary	**mitigation:** Technology changes that reduce emissions, reduces or prevents greenhouse gas emissions. **adaptation:** Adjustment in natural or human systems to a new or changing environment that moderates negative effects, reduces harm to the environment. **resilience:** The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.
Student Learning Outcomes	• Students will be able to explain the difference between adaptation and mitigation, and provide many examples of each. • Students will be able to debate about the positives and negatives of mitigation and adaptation solutions using the CER framework.
Performace Expectation(s) addressed	**MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's system. **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Educator Prep	• Make one copy of *Impacts, Mitigation, Adaptation Prompt Lines.* • Make copies of *Adaptation & Mitigation Scenarios* worksheet for each student. • Make copies of *Claim, Evidence, Reasoning (Mitigation and Adaptation)* worksheet for each student. • Create and post two signs on opposite walls in your classroom. Signs will say "Impacts of Climate Change" and "Actions to Combat Climate Change" and will be used for the Impacts, Mitigation, and Adaptation Activity.

Background Information

Students will apply the information they learned in Lesson 2 about making claims in this lesson. They will research and discuss/debate the many ways of minimizing the effects of climate change. Refer to the CER discussion in the front of this curriculum for more information (page vi and vii).

There are many terms that are used when discussing climate change solutions. Making students aware of the terms and differences between them is important to their understanding of solutions. Mitigation is often used when discussing possible solutions. *Mitigation* involves reducing the severity or seriousness of a problem. We can mitigate the effects of climate change by creating more fuel efficient vehicles or using renewable energy. *Adaptation* means adjusting to new conditions. This means that the effects are already occurring. While mitigation is concerned with reducing future effects, adaption is taking action on the current issues at hand, recognizing that they are already occurring. We can adapt to a changing climate by making upgrades to sewer systems for increased rainfall during storms. These actions will lead to more resilient communities therefore allowing those communities to recover quicker from the repercussions of climate change.

Keep in mind that there are actions that adapt and mitigate the effects of climate change at the same time. These actions include planting trees (they reduce emissions through photosynthesis and provide shade from the heat for animals and humans) and building or expanding a mass transit system in a city (this reduces emissions by eliminating cars on the road and reduces harm in the same way).

Journal Activities

In their journals, students will have definitions of mitigation and adaptation, a drawing of a venn diagram with mitigation and adaptation examples, and a paragraph arguing for mitigation, adaptation, or a combination of both.

Activity Description

Introduction:

1. Ask students if they have heard of the words adaptation or mitigation. Have them do a think-pair-share (think about what the words mean and write a definition in their journal, pair up and talk to their partner about their definitions, and share with the class). Let the class discuss and explain how they came up with their definitions. We will come back to this after a couple of activities. Leave space on this page to write the final definition later.
2. Show students a video that illustrates what they would need to minimize their impacts and the impacts of others. These three videos will help introduce the terms adaptation and mitigation and can be found at http://www.climategen.org/ngconline.

> *The scientific understanding of climate change is now sufficiently clear to justify taking steps to reduce the amount of greenhouse gases in the atmosphere.*
>
> *- U.S. National Academy of Sciences*

a. *Climate Change 2014: Mitigation of Climate Change* would be great to use with older or advanced students. This video discusses where greenhouse gases come from, what future climate change will look like, and how humans can mitigate for a cleaner future. It discusses these things from a science and social studies perspective.
b. *Climate Change Adaptation* and *Mitigation* are shorter and focus on the definitions of adaptation and mitigation and how they are being used to combat climate change

Activity 1: Impact, Adaptation, Mitigation Activity

1. Post two signs on opposite walls in your classroom: "Impacts of Climate Change" and "Actions to Combat Climate Change."
2. Have students get into groups of two. Pass out one of the prompts from the *Impacts, Mitigation, Adaptation Prompt Lines* sheet to each set of partners. Explain that the students will need to discuss their prompt with their partner, move closer to the wall that best fits their prompt, and be able to justify their response.
3. Draw the *Venn Diagram* on the board or make one on a large piece of paper. Have students with the Actions to Combat Climate Change place their prompt in the Venn diagram that best describes their prompt (mitigation, adaptation, or both). Have students with Impacts of Climate Change statements decide which of these actions would combat their impacts and have them include their impact in the correct circle. Before moving on, have students draw the Venn Diagram in their journals with all responses included.
4. Have a discussion about why students placed their impacts and actions where they did. Come up with other examples of ways to mitigate and adapt to climate change. Are there mitigation and adaptation techniques on these lists that you could participate in?
5. Next, the students will examine the *Adaptation and Mitigation Scenarios* worksheet in groups of 4 (two sets of partners). For the first task, students will examine two scenarios, identify the climate change impact, and the adaptation or mitigation actions that took place. Students will also explain why they are actions of mitigation and/or adaptation. In the

second task, students will create their own Climate Change Scenario that includes an impact, a response to mitigate and/or adaptation to the situation, and an explanation.

Activity 2: National Climate Assessment Part II

1. Return to the introduction at the beginning of this lesson, have students take out their journals. Have students write out the definitions of adaptation, mitigation, and resilience (see vocabulary section).
2. Students will use the National Climate Assessment again, but this time they will be finding ways people are minimizing the impacts of climate change. Within the NCA Report, students will click on 'Response Strategies.' There are five areas that the students can look at to find out what option they think is the best to minimize climate change: Decision Support, Research Needs, Sustained Assessment, Mitigation, and Adaptation. For lower grades, use just the mitigation and adaptation sections. (This will avoid confusion for students and keep them focused on choosing just one of the ideas, but still be able to find evidence to back up their position.)
3. Students will be collecting evidence that supports a claim they make about what response is best, mitigation or adaptation. Students will use a similar worksheet as in Lesson 2. The worksheet for this lesson; *Claim, Evidence, Reasoning (Mitigation and Adaptation)* does not have an area for data collection but still provides an outline for their claim, evidence, and reasoning. After finding data, have students make their claim. They will then cite evidence from the NCA site and explain their reasoning to finish the worksheet.

Conclusion

Using the *Claim, Evidence, Reasoning (Mitigation and Adaptation)* worksheet, students will discuss and debate which strategy they claimed is 'best.' They will need to utilize their evidence and reasoning as they talk with their classmates. Ask students to write in their journals a paragraph arguing for mitigation, adaptation, or a combination of both.

Extensions

Ecological Footprint Quiz

1. Have students take the Ecological Footprint Quiz to see what their impact is on the earth. They will answer the question: How many planets does it take to support my lifestyle? After the quiz, students will think of ways they can minimize their impacts, including ways to mitigate and adapt.
2. Students will go to the following website: http://www.earthday.org/footprint-calculator to complete their footprint quiz. Note: This footprint quiz only runs with Flash. Be sure your computers are setup with Adobe Flash before beginning. There are many other quizzes available. This one was chosen for its great visuals.
3. Directions to take the quiz:

    a. New Users- click on 'Get Started'
    b. Create an Avatar
    c. Enter Basic or Detailed Information for each category (encourage students to enter as much Detailed Information as they can, as their results will be better.)
    d. The quiz will collect information from the following categories: your food (where and what you eat), your home (recycling habits, dwelling type, energy usage), your mobility (car mileage and mpgs, public transit usage, and flights). The results of this information will give students their collective ecological footprint on the planet.
    e. When they have completed the quiz, students will review their results. The results page is divided into four sections: number of planets to support their lifestyle, a pie chart of how their Ecological Footprint breaks down, the number of acres needed to grow and raise food and products, and a place to edit and explore various scenarios to change their footprint.

4. Students will need to edit parts of their quiz to see how they can change their footprint. They need to write in their journals about how they could minimize their impact (what they will need to do, how much their impact changed). They should have 4-5 items written down about what they changed and how their impact increased or decreased. They can also reflect on the activity with this question: what things caused the most dramatic changes in your footprint? Answer in a detailed paragraph.
5. Facilitate a discussion about what things they can do after seeing their results.

Watch "Minnesota Stories in a Changing Climate."
1. This one-hour video discusses six Minnesotans and their stories about impacts of climate change on their lives and how they are adapting or mitigating to those changes. Find it at www.climateminnesota.org.
2. During the video, students should take notes in their journals. Have students make a T Chart in their journals. Write "Monitor" on one side and "Minimize" (also list if it is a form of adaptation or mitigation) on the other.
3. After the viewing, use the TPT video discussion guide to ask students questions and have a discussion about the video. Use the discussion questions featured in each section.
4. If you aren't in Minnesota think about how these stories are similar or different to those you might tell in your state.

Resources
What's your favorite carbon calculator? http://www.climategen.org/blog/carbon-calculators-reviewed/

References
Impacts, Mitigation, and Adaptation Prompt Lines and Adaptation and Mitigation Scenarios adapted and used with permission from Region of Peel Integrated Planning Division. http://www.peelregion.ca/planning/teaching-p

Impacts, Mitigation, and Adaptation Prompt Lines

1. Intense high wind weather event hits the St. Cloud area of Minnesota. Wind storm causes damage to homes and businesses. Roofs and cars are damaged. Clean up costs exceed $2 million.

2. Increase in seasonal snowfall causes high runoff of snowmelt; resulting in flooding of Minnehaha Creek. Basements are flooded.

3. Record heat wave hits Chicago. Power outage occurs due to high demand to power cooling systems.

4. Midwest farmer loses crop due to extreme ice storms; three years in a row.

5. The numbers of leopard frogs found in the wetland are slowly decreasing.

6. The Sioux Falls area host a community Tree Planting Day.

7. The City of Rochester, NY upgrades sewers, culverts and overland flow routes for extreme rainfall

8. The City of Portland, OR expands the transit system

9. The City of builds more biking and walking paths. A new website includes an interactive map that will allow cyclists and walkers to plan their trips.

10. A new recycling plant is built and it is heated and cooled by ground source heat pumps (no direct use of fossil fuels).

11. A Solar Thermal Hot Water system is installed at Children's Hospital.

12. There are indoor recreation programs offered on extreme heat days.

13. Two children's splash pads are built in the area.

14. One acre of forest land is donated to the City of St. Louis. The land will be protected as parkland.

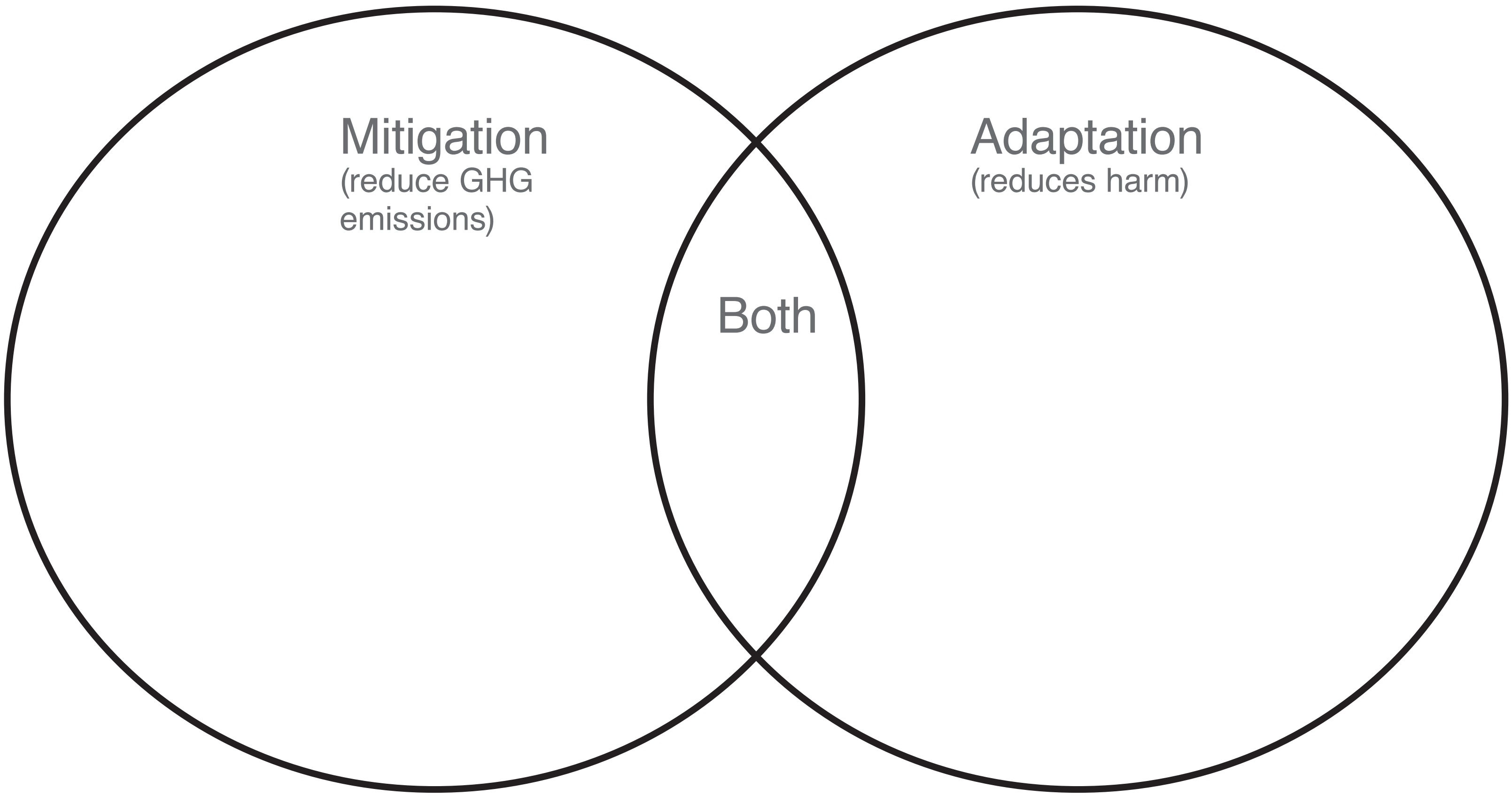
15. Drive-thrus are no longer permitted in the Downtown areas of Seattle.

16. Cooler uniforms are given to staff working outside in the summer.

Suggested answers: (I- 1, 2, 3, 4, 5) (A- 6, 7, 10, 12, 13, 16) (M- 6, 8, 9, 10, 11, 14, 15)

Adapted and used with permission from Region of Peel Integrated Planning Division.

Mitigation and Adaptation Venn Diagram



Name ______________________________

Student Worksheet: Adaptation and Mitigation Scenarios

Task 1: Examine the scenario below. Identify the climate change impact, and the adaptation or mitigation actions that took place. Explain why they are actions of mitigation and/or adaptation.

Scenario 1: Due to extreme ice storms over the past month, a 70 year old woman is unable to purchase groceries. She calls a local food bank organization to deliver her food to her apartment.	
Impacts:	Why is this a climate change impact?
How was the impact Adapted and/or Mitigated:	Why is this action considered to be a mitigation or an adaptation to climate change?
Scenario 2: Increased temperatures over time in Caledon has lengthened the growing season for the farmer. The farmer has calculated that the crop can be grown twice during the season. This will double his farming profits.	
Impacts:	Why is this an impact?
Adaptation/Mitigation or both:	Why is this action considered to be a mitigation or an adaptation to climate change?

Task Two: Create your own Climate Change Scenario that includes an impact and a response to mitigate and/or adapt to the situation. Explain your thinking. If necessary, you may use resources around the classroom or the internet.

Adapted and used with permission from Region of Peel Integrated Planning Division.

Name ______________________________

Student Worksheet:
Claim, Evidence, Reasoning (Mitigation and Adaptation)

After searching for information about adaptation and mitigation, write a claim that answers the question: What is the best option for minimizing the repercussions of climate change?

Claim

(Write a sentence stating the best option for minimizing repercussions of climate change? Be as specific as possible and include if your option is an adaptation or mitigation technique.)

Evidence

(Provide scientific data to support your claim. Use evidence (graphs, tables, etc.) from the National Climate Assessment website.)

Reasoning

(Explain why your evidence supports your claim. Why is your evidence important? Describe what it means to minimize certain repercussions and why your evidence allowed you to determine that your option is the best one.)

Age Level	Grades 6-8
Time Needed	Two 50 minute class periods (plus more time outside class for data collection)
Vocabulary	**engineering:** The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.
Student Learning Outcomes	• Students will be able to use the engineering design process to create a way to monitor and minimize climate change.
Performance Expectation(s) addressed	**MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
Educator Prep	• Some student ideas may need approval from your principal or superintendent. Be prepared to ask for permission or limit the actions that your students can take in this lesson.

Background Information

In this lesson students will use the process of engineering design to create a way to minimize and monitor climate change. For this activity we consider a simple outline of the engineering process (there are many):

a. Define the problem and resources available
b. Brainstorm solutions
c. Develop a plan
d. Test your plan
e. Improve the plan
f. Analyze the plan and use it

As the educator, you have the choice to limit this creation to something the students create in the classroom, regarding just themselves, or extend their reach out into the world. They could create a plan to monitor and minimize something in their house, at their school, or across their state. It could be a real project or one that is so big that it can only be conceptualized.

> *We can reduce the risks we will face from climate change. By making choices that reduce greenhouse gas pollution, and preparing for the changes that are already underway, we can reduce risks from climate change. Our decisions today will shape the world our children and grandchildren will live in.*
>
> *- Environmental Protection Agency*

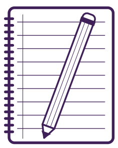
Here are a few examples:

- Monitor idling cars at the end of the school day. Make a plan to help minimize the number of cars/buses that are waiting to pick kids by creating no-idling zones.
- Monitor the amount of rain water runoff around school. Create a plan to minimize rainwater runoff and wasted water by installing a rain garden.
- Monitor the amount of food waste at lunch. Make a plan to minimize that waste by implementing a compost system.

Lesson 6: How can you design a method for monitoring and minimizing climate change?

Your solution to minimize a climate change

At this point, students have learned the ways humans impact the climate; the ways scientists and citizens can monitor the climate; and ways to minimize climate change impacts. Now, students will brainstorm ways they can monitor climate change, knowing there are many different indicators, and develop ideas on how they can minimize the repercussions. Emphasize to the students that there are many possible solutions and creativity with foundation is encouraged!



Journal Activity

Students will use their journals to brainstorm ideas, create a plan, and collect evidence and information for their design to monitor and minimize climate change.

Activity Description

Introduction:

Review repercussions of climate change from Lesson 3, methods of monitoring impacts from Lesson 4, and minimizing from Lesson 5. Have students use their notebooks as a reference by having them go back to each lesson and share important things they remember or learned from that lesson.

Activity: Your Solution

1. Students will split into small groups (or work individually) to design a way to monitor and minimize climate change. They will need to use the information they have collected about what is causing the global temperature to rise, mitigation and adaptation to climate change, and how to monitor the repercussions.
2. This activity is an opportunity to discuss the process of engineering design:
    a. Define the problem and resources available:
        i. What is the problem? How have others approached it?
        ii. What are your constraints?
        iii. Prompt the students with questions that relate to defining the problem. For example, what did you learn about climate change in the graphs of Lesson 2 or from the National Climate Assessment? If we were going to make a statement about climate change affecting the students at this school, what might we say? What are some examples of mitigation? What are some examples of adaptation?
        iv. This activity is an opportunity for students to do some additional research on the topic they choose.
    b. Brainstorm solutions:
        i. What are some solutions? Brainstorm ideas. Choose the best one.
    c. Develop a plan:
        i. Draw a diagram or write out your plan. Make lists of materials you will need.
        ii. Give students the opportunity to develop a plan. Be sure they create a template or drawing for collecting their "monitor" data and have ideas about how they will minimize. But they should know that those ideas can change depending on their data collection.
    d. Test your plan:
        i. Follow your plan and test it or begin monitoring.
        ii. Discuss ways of testing their design. This might include sharing the design/plan with classmates and getting suggestions.
    e. Improve the plan:
        i. What worked? What didn't? What could work better? Modify your plan to make it better. Test it out again.
        ii. Get feedback from students and based on that feedback ask the students to make some modifications of their plan.

f. Analyze the plan and use it:
   i. Ask students to write up a description for their plan that includes some reasons why they think it is important.

3. Students will design a method to monitor and minimize a climate change impact they see around their school, home, or town. They could also think bigger and design something that would monitor and minimize in their state or country.

Take It Outside

The information may been to be collected outside of school hours, possibly after school or at home.

4. Students will need to design a way of monitoring their chosen problem. This could include watching for an amount of time and recording information in a data table or installing a device to record information (rain gauge).

5. Once they have collected information about monitoring a climate change impact, they will need to think about how they can minimize that impact. Will this project include mitigation or adaptation or both?

Conclusion

Students will write a letter to their school administration, city council, or other policy maker about their project. The letter should address their plan to monitor and minimize a human impact, what evidence they collected, and their conclusions from the project. Students could ask for support in creating change around their project.

Assessment

Teachers should collect journals at this point if using them as an assessment tool.

Extensions

Teachers could apply for grants to pursue actions with their classrooms.

References

Engineering design process steps were adapated from: http://www.eie.org/overview/engineering-design-process